AGE OF AN EARLY DEVONIAN CARBONATE FAN AND ISOLATED LIMESTONE CLASTS AND MEGACLASTS, EAST-CENTRAL VICTORIA

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Conodont data are presented for stratigraphic sections through Early Devonian carbonate units of the Coopers Creek Limestone in the Tyers–Boola area, and for isolated limestone megaclasts, and limestone boulders from debris-flows in the Early Devonian flyschoid sequences in the nearby Deep Creek–Marble Creek and Platina–Coopers Creek areas of east-central Victoria.

The conodont data from the Tyers–Boola area indicates that, *contra* traditional views, the limestones of this area do not represent a single conodont zone (*sulcatus* Zone) but span parts of two conodont zones as well as all of two others, from late in the *sulcatus* Zone to early in the *dehiscens* Zone, spanning most of the Pragian and extending into earliest Emsian, i.e. 30% or so of Early Devonian time. It is argued that the rich shelly fauna of the uppermost Boola Formation is probably very early Pragian.

Conodonts from richly fossiliferous limestone boulders in debris flows and from isolated megaclasts in the Platina–Coopers Creek and Deep Creek–Marble Creek areas in the southern part of the Walhalla Synclinorium, though mostly not compelling as to age, include a megaclast (Evans Quarry, Coopers Creek), at the base of the Wilson Creek Shale, with a *kindlei* Zone (mid-Pragian) conodont fauna. The age indicated for the Wilson Creek Shale, and thus presumably for entry of the regionally important graptolite *Monograptus thomasi thomasi*, characteristic of it, is no older than *kindlei* Zone. Other limestone boulders and megaclasts of the region appear to be early Pragian or even Lochkovian, antedating the onset of carbonate sedimentation in the vicinity of the Tyers–Boola carbonate fan. They are evidence for a former tract or tracts of shallow water carbonates (a 'lost' carbonate platform) accumulated during the Lochkovian–early Pragian, and lithified prior to incorporation in the Boola, Wurutwun and Wilson's Creek formations. Other evidence suggests this landmass, with exposed Cambrian greenstones, lay to the south of the Tyers–Boola area. The latest Pragian or perhaps earliest Emsian limestone megaclasts farther north at Loyola, emplaced in the Norton Gully Sandstone, are substantially younger than any of those of the Platina–Coopers Creek and Deep Creek–Marble Creek areas in the southern part of the Walhalla Synclinorium; they were coeval with the youngest carbonates of the Tyers–Boola carbonate fan.

EARLY Devonian (Pragian and Emsian) limestones are widespread in south-eastern Australia. In an earlier paper (Mawson et al. 1992) attention was directed to sequences about the Pragian–Emsian boundary, primarily the Buchan Caves Limestone and Wentworth Group in eastern Victoria, and the Cavan Formation at Wee Jasper in southeastern New South Wales. Attention is here directed to a group of generally older limestones in the Tyers–Boola, Platina–Coopers Creek and Deep Creek–Marble Creek areas of east-central Victoria. The limestones of the Tyers–Boola area have been interpreted as a carbonate fan (Rehfisch & Webb 1993). Limestone occurrences elsewhere in the southern part of the Walhalla Synclinorium (see Appendix) are regarded as allochthonous; these include isolated megaclasts (Conaghan et al. 1976). Closer investigation of the conodont faunas from these occurrences was judged worthy for the following reasons:

1. Preliminary sampling of the Tyers–Boola area demonstrated an abundance of Pragian conodonts; these included several previously unreported species and several morphs of *Eognathodus sulcatus* Philip suggesting much of Pragian time might be represented. Globally, there is a dearth of well documented Pragian (mid-Early Devonian) sequences; the Tyers–Boola successions were thus deemed to have potential for yielding data of more than local significance including, possibly, information on the pattern of conodont biofacies during Pragian time.
2. Tyers quarry was the type locality for four new species of conodonts including the zonally important early Pragian form *E. sulcatus*; these

were obtained from a bulk sample representing 'different lithologies exposed in the quarry' (Philip 1965, p. 95) and thus, potentially, an appreciable time-span. Determination of the ranges of these earlier identified forms relative to the newly identified species was therefore desirable. Additionally, re-sampling could provide useful information on intraspecific variation within *E. sulcatus*.

3. Horizons referred to the Coopers Creek Limestone (or Formation) in the past, and to horizons above and below it, include isolated limestone megaclasts as well as debris flows and carbonate fan deposits (Conaghan et al. 1976; VandenBerg 1988; Mawson et al. 1992; Rehfisch & Webb 1993), the last specifically in the Tyers–Boola area. No age-constraining conodont data have been presented for these carbonates apart from a bulk sample from Tyers (Philip 1965), and from megaclasts at Loyola (Cooper 1973a; Mawson et al. 1992).

4. Graptolites, including the widely distributed *Monograptus thomasi* Jaeger, have long been known from the Wilson Creek Shale. The latter was once thought (Baragwanath 1925) to antedate the Coopers Creek Limestone but is now regarded as a facies equivalent of some or all of the Coopers Creek Limestone; neither unit is now included in the Walhalla Group (VandenBerg 1988, p. 112–115). Age-data based on conodonts from the Coopers Creek Limestone could thus have implications for correlation of the globally important graptolite faunas.

The following abbreviations are used for conodont genera throughout the text, on figures and tables: *Anc.* = *Ancyrodelloides*, *Amy.* = *Amydrotaxis*, *B.* = *Belodella*, *D.* = *Drepanodus*, *E.* = *Eognathodus*, *I.* = *Icriodus*, *N.* = *Neopanderodus*, *O.* = *Oulodus*, *Pa.* = *Panderodus*, *Pand.* = *Pandorinellina*, *Ped.* = *Pedavis*, *P.* = *Polygnathus*. Abbreviations used for stratigraphic sections are TQ = old Tyers Quarry, and BOO = Boola Quarry. Spot localities sampled are shown on Figs 1–3. It should be noted that wherever the word zone is used in the following text we imply the current zonal scheme for the Early Devonian, based exclusively on conodonts.

SEQUENCES INVESTIGATED: STRATIGRAPHIC BACKGROUND

Limestone bodies of Early Devonian age occur on several horizons on both flanks of the Walhalla Synclinorium. They and associated coarse clastics were once thought to represent a single horizon (Herman 1901; Whitelaw 1916; Junner 1920; Baragwanath 1925; Skeats 1928; Thomas 1942) that could be traced from the Loyola occurrences near Mansfield (Cooper 1973a; Mawson et al. 1992) to Tyers, where they disappear beneath the Gippsland Basin. It should be noted that, though these limestones were assumed to be autochthonous, two workers (Murray 1878, 1887, 1895; Kitson 1925) had clearly recognized the discordant relationship between the main limestone bodies and enclosing strata at Marble Creek and Deep Creek. This was prior to recognition that such bodies could, sedimentologically, be far-travelled. Junner (1915) and Thomas (1942) pointed out that the limestone bodies about Coopers Creek occurred on different horizons. Boundaries of the tract interpreted by Thomas as basal conglomerates [= Coopers Creek Formation of Philip 1960a, 1962] of the Walhalla Group, incidentally, differ significantly from the interpretation proffered by VandenBerg (1975 and in VandenBerg & Garratt 1976, Fig. 4.5) where the two main limestone occurrences in the vicinity of Coopers Creek, the White Rock and Evans Brothers' quarries are shown to be about *c.* 100 m apart stratigraphically, the former below and the latter interpreted as occurring within the Wilson Creek Shale. It should be noted that excision of the 'basal conglomerates' from the Walhalla Group (VandenBerg 1977a, 1988) might be viewed as marking a substantial departure from earlier practice in which this unit, regarded as marking a regionally identifiable change in sedimentation, was taken to mark the base of the Walhalla Group (Whitelaw 1916; Skeats 1928; Baragwanath 1925; Thomas 1942; Philip 1960b, 1962, 1968). VandenBerg (pers. comm.) has concluded, from extensive field work, that the 'basal conglomerates' of the above cited authors cannot be aligned precisely from area to area; it is therefore not possible to identify a regional change in sedimentation with any sort of precision.

A major exercise in re-definition of stratigraphic units for the region was undertaken by VandenBerg (1975) as background for revised mapping that covers a broader area, especially to the north, than that considered here. These publications, coupled with a recent synthesis of the stratigraphy and structure of the region (VandenBerg 1988), provide a useful starting point for understanding the stratigraphy of the areas probed in this report. It should be noted that because of difficulties in applying stratigraphic nomenclature from the western to the eastern flank of the Walhalla Synclinorium, a new name, Wurutwun Formation has been introduced for a conglomerate-siltsone interval beneath the Walhalla Group (Carey & Bolger in VandenBerg 1988; Bolger & Carey, in prep.). It should also be noted that the generally accepted view regarding the turbiditic Walhalla Group and underlying formations of east-central Victoria is that they are primarily deep water (VandenBerg in VandenBerg & Garratt 1976; VandenBerg 1988). A dissenting explanation, that they are shallow marine deposits, nevertheless continues to have its protagonists (Garratt 1983a, p. 123; Weir et al. 1988). Papers on chitinozoans from stratigraphic sections through the limestones in the Tyers and Boola quarries (Winchester-Seeto 1993), and on carbonate petrology of the Tyers–Boola carbonate fan (Rehfisch & Webb 1993) have appeared recently. Manuscripts are in preparation on stratigraphy in the Deep Creek area (Bolger & Carey, in prep.), on dacryoconarids (G. K. B. Alberti, pers. comm.), and on conodonts from autochthonous limestones from the Wilson Creek Shale in Jacob's Creek at Moondarra, and from the Thomson River below Coopers Creek (Carey & Bolger ms.). We are not especially concerned here with questions of priority in application of stratigraphic nomenclature, nor with the possibility of diachronism regionally, though we would submit that there still seem to be substantial difficulties in applying a consistent, high-resolution stratigraphy throughout this south-eastern portion of the Melbourne 'Trough'. Our prime concern is documentation of the conodonts from the Tyers–Boola area, and from various limestone bodies in the southern part of the Walhalla Synclinorium, and probing their chronological and palaeogeographic implications.

1. Tyers–Boola area

Murray (1876, p. 140, 1887, 1889, 1895) was the first to report on the Early Devonian limestones of the Tyers–Boola area (Fig. 1). The occurrence he described is clearly the body cropping out rather poorly in the steep gully informally called Murray's Gully on Fig. 1, a repetition by folding of the main belt of limestones extending through the Tyers and Boola quarries. The latter tract was elegantly surveyed in 1926 by Kenny (1937). The stratigraphy and palaeontology of the entire area were comprehensively investigated by Philip (1960a, 1960b, 1962, 1965). Philip (1960b, 1962) suggested that the boundary between the Boola Beds and the Coopers Creek Limestone should be taken as closely approximating the Silurian–Devonian (Pridoli–Lochkovian) boundary. Subsequently, on the basis of conodonts he concluded that an 'Upper Gedinnian or early Siegenian' age [approximately late Lochkovian–early Pragian in modern parlance] was more likely for the Coopers Creek Limestone (Philip 1965). One must assume, incidentally, that Philip intended the type sections of his Coopers Creek Formation to be in the vicinity of Coopers Creek, and the type section of his Boola Beds to be in the Tyers–Boola area, presumably one or other of the Tyers River or White's Creek sections, but type sections were not specifically designated. Philip (1960b, 1962) initially believed there had been continuous sedimentation from the Boola Beds into the Coopers Creek Limestone but subsequently (Philip 1965, 1968), on the basis of channels with conglomeratic sediments (including limestone boulders) cut into the Boola Siltstone, suggested unconformable relationships and a major 'regional unconformity' causing 'strata of different ages [to be] brought beneath the Coopers Creek Formation along its strike length' (Philip 1968, p. 915). Subsequent work by VandenBerg (1975, 1988) and others has demonstrated a very different pattern of regional stratigraphic alignments compared with the interpretations presented by Philip, though VandenBerg (pers. comm.) believes channeling of the Boola Formation at the base of the Coopers Creek Limestone may be connected with a minor diastem.

In the Tyers–Boola area, where carbonates predominate over other lithologies in the Coopers Creek Formation (*sensu* Philip), the careful mapping and borehole information presented by Kenny (1937) is indicative of a very important non-carbonate component (conglomerates, shales) and considerable complexity in lithofacies relationships. VandenBerg (1975, 1988), clearly influenced by the predominance of limestone over other lithologies in the Coopers Creek Formation (*sensu* Philip) in the Tyers–Boola area, suggested modification of the name to Coopers Creek Limestone. He had, however, applied the name Coopers Creek Formation to large tracts of siltstone and sandstone, devoid of carbonates apart from rare allochthonous blocks, in the Platina–Coopers Creek and nearby Telbit Crossing areas (VandenBerg & Garratt 1976, Figs 4.4 and 4.5) underlying the Wilson Creek Shale. This clastic sequence was to become the Boola Formation (VandenBerg 1975, 1988, Fig. 4.4), with a designated type section on the Erica–Walhalla road rather than in the Tyers–Boola area. This action effectively made the Boola Formation *sensu* VandenBerg more or less a synonym of the Coopers Creek Formation *sensu* Philip of the Platina–Coopers Creek but not Tyers–Boola area. In addition to being not in accord with Philip's intentions, this action was not in harmony with the spirit of the Australian Code of Stratigraphic Nomenclature. That notwithstanding, we appreciate VandenBerg's pursuit of a regionally consistent stratigraphic framework and have there-

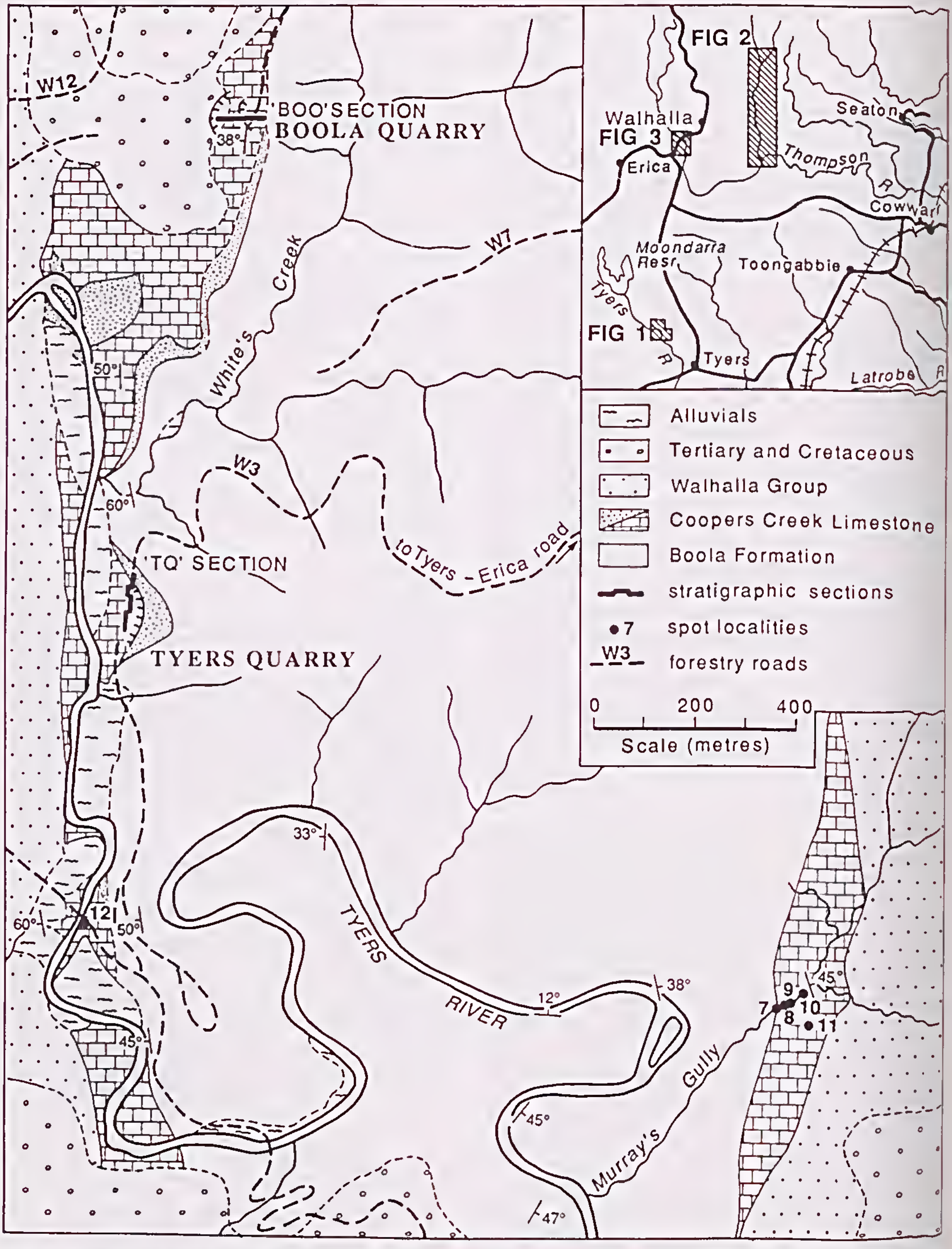


Fig. 1. Geology of the Tyers–Boola area, Victoria, based on mapping by Kenny (1937) and Philip (1962) showing location of stratigraphic sections and spot localities sampled. Note simplified representation of Coopers Creek Limestone: limestones by brick-pattern, mudstones, sandstones and conglomerates by stippling.

fore adopted his recommendations, though with some reservations arising from Kenny's (1937) demonstration of an important non-carbonate component within the carbonate sequence of the Tyers–Boola area. We nevertheless use VandenBerg's modification of Coopers Creek Formation to Coopers Creek Limestone, with application restricted to the Tyers–Boola area.

On the basis of thin sections, Chapman (1907) presented preliminary identifications of several species and descriptions of 3 new species from Tyers River (presumably from the old Tyers Quarry): a cyanophyte *Girvanella conferta*, a tabulate coral *Caunapora australis* [=*Favosites squamuliferus* forma *stelliformis* Chapman] and a supposed bryozoan, *Rhombopora gippslandica*; the last is a tabulate coral now referred (Philip 1962) to *Cladopora*. The macrofauna of the Tyers–Boola area was comprehensively described by Philip (1960a, 1962). The taxonomy of some of the rugose and tabulate corals has since been revised (Pedder 1965, 1967; Strusz 1966, 1968; Jell & Hill 1969; Hill 1978), as have the brachiopods (Talent et al. 1993), and the stromatoporoids (Webby et al. 1993). The conodont fauna from Tyers Quarry described by Philip (1965) included a new form, *Eognathodus sulcatus*, which subsequently became the nominate species for the early Pragian *sulcatus* Zone, though inference of the significance of an interval characterized by *E. sulcatus* was made on biostratigraphic data from North America. Cooper (1973b) reported the occurrence of the usually Pragian dacryoconarid *Nowakia acuaria* from limestone in the old Tyers Quarry. The limestones and interbedded clastics of the Tyers–Boola area have been interpreted recently (Rehfisch & Webb 1993) as a primarily carbonate fan, deposited in deep water.

2. *Deep Creek, Walhalla*

The deeply incised valley of Deep Creek, east of Walhalla, has one salient body of limestone (near the 'Middle Crossing', Fig. 2, loc. 4), closely

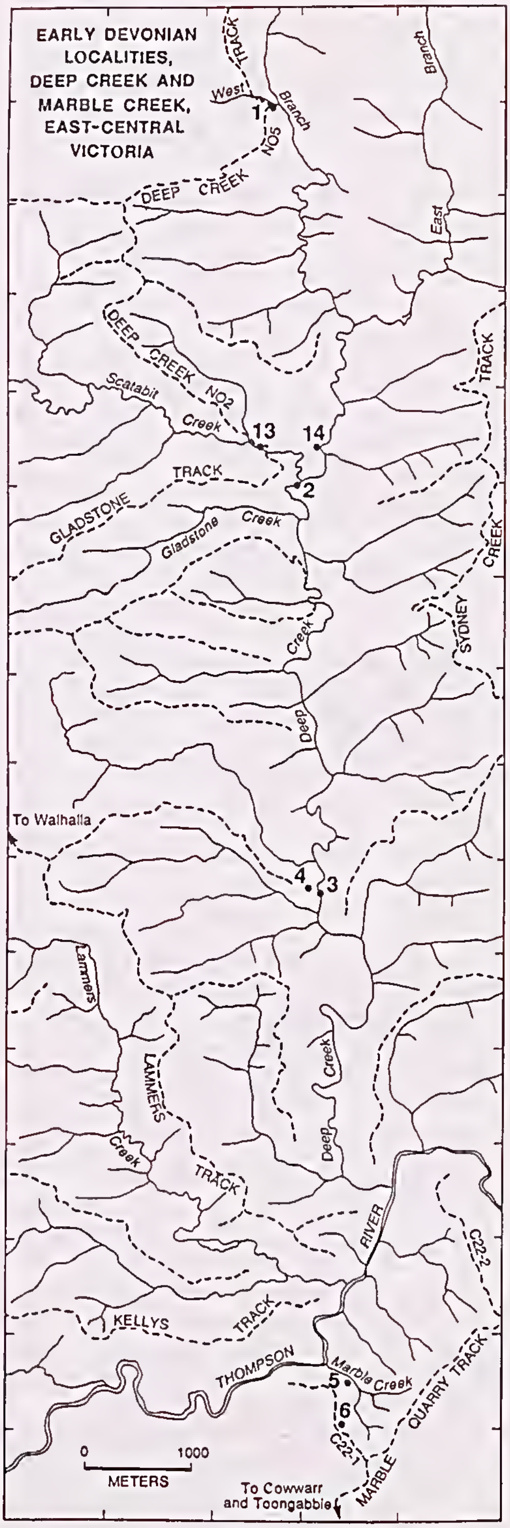


Fig. 2. Location of spot samples from Early Devonian carbonates in the watersheds of Deep Creek and Marble Creek, east-central Victoria. The base map is from Vicmap 1:25 000 topographic sheets Beardmore (8122-2-1), Deep Creek (8222-3-3), Porters Creek (8222-3-4) and Walhalla (8122-2-2). Formational boundaries are not shown because recent mapping has resulted in substantial changes in boundaries and nomenclature; this should soon be available (Bolger & Carey ms.). An earlier interpretation of formational boundaries may be obtained from the Geological Survey of Victoria 1:250 000 geological map SJ55-6 Warburton (VandenBerg 1977b).

associated with coarse clastics including clasts of fossiliferous limestone. This occurrence, together with the Marble Creek limestones (Fig. 2, locs 5 and 6) and other minor carbonate occurrences on the same general north-south trend would formerly (e.g. Baragwanath 1925, Skeats 1928) have been construed as the eastern belt of fossiliferous conglomerates and grits marking the base of the Walhalla Beds (later Walhalla Group). We have sampled carbonate outcrops at 8 localities in the Deep Creek–Marble Creek tract (Fig. 2); these plot up as occurring in three stratigraphic units on the most recent geological map covering the area (VandenBerg 1977b). Because geological boundaries and stratigraphic nomenclature for the Deep Creek–Marble Creek area will be substantially modified in due course (Bolger & Carey ms.), we have refrained from using former boundaries and nomenclature on Fig. 2. Descriptions of the carbonate occurrences sampled by us, other than the 'Middle Crossing' occurrences (locs 3 and 4) given below, are provided in the Appendix.

An approximately 30 × 40 m limestone body, interpreted by us as a megaclast, outcrops boldly on the right (west) flank of Deep Creek about 0.25 km upstream from the former 'Middle Crossing', Deep Creek (Fig. 2, loc. 4). This is the limestone which Murray (1878, p. 48, Fig. 4) recognized as discordant and therefore probably Devonian because of 'rest[ing] *on* the upturned edges of the latter ['Silurian strata']. The limestone yields tabulate and rugose corals, is occasionally crinoidal, but seems to be without silicification of fossils. Despite being located *c.* 5.5 km east of Walhalla, this was clearly the limestone in Deep Creek reported by Murray (1878, 1887, p. 45, 1895, p. 38) and source of *Fenestella australis* Chapman and brachiopods referred to *Plectambonites* reported by him (Chapman 1903) from limestones in Deep Creek '7 miles south-east of Walhalla'. Chapman (1912) gave preliminary identifications of material collected by Baragwanath from this limestone body; subsequently he (Chapman 1914) reported a stromatoporoid and 6 species of tabulate corals. It is the type locality for two of these, *Favosites nitida* Chapman [now *Squameofavosites nitidus*] and *Pachypora* [now *Thamnopora*] *alterivalis* (Chapman). Later he (Chapman 1921) described another new species, *Favosites* [now *Emmonsia*] *spinigera* and identified *F. forbesi* Edwards & Haime [= *S. nitidus*] from loc. 4. Two new species of gastropods, *Platyceras minutum*, and *Diaphorostoma* [now *Platyceras (Platyostoma)*] *incisum* described by Chapman (1916) are assumed to have come from loc. 4. These species were revised by Tassell (1977) who, in addition, recorded *Cowwarrella cylindrica* and *Oriostoma* n. sp. from loc. 4.

Stratigraphically beneath the aforementioned limestone body, outcropping in the bed of Deep Creek, are sandstones and polymict conglomerates, including crinoidal limestone clasts up to 0.5 m across (Fig. 2, loc. 3).

3. *Marble Creek*
(Old Toongabbie marble quarries)

Kitson (1925) reported on the two richly fossiliferous crinoidal limestone bodies at Marble Creek, formerly quarried for decorative stone. The upper quarry, 'on the brow of a steep hill', was being worked prior to 1887 (Murray 1887, p. 46). Murray had noted that 'downward the limestone disappears, and nothing [i.e. no limestone] can be seen along the face of exposed rock below the quarry' (Murray 1987, p. 46, 1895, p. 38). Kitson noted that the limestone body in the lower quarry, 12.8 m in thickness, is 'not evenly bedded with the slates, but has a very irregular margin, both on the upper and lower side and at the north end' where his figure (Fig. 132) shows the limestone to be abruptly replaced, along strike, by slates. Kitson's and Murray's observations are consistent with interpretation as allochthonous blocks lithified before incorporation in the enclosing argillites (Conaghan et al. 1976, p. 529). Murray (1887, 1895) noted a third body outcropping in Marble Creek, 'a couple of feet long and one foot thick, thinning out to nothing upwards and downwards and entirely enclosed by slates'; an additional minor body of limestone, farther north, was noted by Kitson (1925). Brachiopods (Talent 1956b; Talent et al. 1993), mollusks (Talent & Philip 1956; Tassell 1977, 1982), crinoids (Philip 1961) and a trilobite (Holloway 1991) have been described from the two quarries. Among the new taxa of gastropods proposed by Talent & Philip (1956) were two new genera based on species from Marble Creek: *Cowwarrella* and *Ostlerina*. Knight et al. (1960) placed these in synonymy with *Visitator* Perner and *Platyostoma* Conrad respectively. There is so little similarity between *Visitator* and *Cowwarrella* that we prefer to regard them as discrete and not closely related genera; we believe *Ostlerina* to have value as a distinctly phaneromphalous subgenus of *Platyceras*. No conodonts have been described from the Marble Creek quarries but a sample with a mixture of conodonts from Deep Creek (our loc. 4) and Marble Creek (locs 5 and/or 6) was reported as having *Ozarkodina remscheidensis*, *O. excavata wurmi* and an Sc element of ?*Amydrotaxis*, suggesting a late Lochkovian age (Pickett in Holloway 1991).

4. *Coopers Creek and Tyers Junction*

Limestones have long been known from the Platina–Coopers Creek area (e.g. Murray 1878, p. 48, 1887; Herman 1901; Junner 1915). Thomas (1942) pinpointed 6 significant occurrences of limestones in the area (Fig. 3), two of them sizeable. Both contain abandoned quarries in highly fossiliferous limestones, the White Rock (=Commonwealth Sugar Refineries Quarry) and Evans Brothers' quarries. Unlike the Marble Creek and Middle Crossing Deep Creek limestone bodies, the White Rock occurrence was not a homogeneous body of limestone. VandenBerg (1975) reported it as consisting of 'two tilted limestone megaclasts enclosed in structureless siltstone'. Other limestone megaclasts may have been present. D. E. Thomas (pers. comm., *c.* 1956) reported the occurrence as having been an agglomeration of discrete limestone blocks that he described as 'giving out' abruptly into mudstone and then back into limestone again, an observation consistent with interpretation as part of a megabreccia or megaconglomerate. The difficulty this presented in mining was said to have been the main reason for its closure *c.* 1949 (D. E. Thomas, pers. comm.).

McCoy (in Murray 1887, p. 45) gave preliminary identifications of corals, a bryozoan and an ostracode from 'Cooper's Creek' but it was not until 1914 that any taxa were illustrated or described. Chapman (1914) described two new taxa, *Cyathophyllum* [now *Martinophyllum*] *approximans* and *Heliolites interstincta* var. *gippslandica* [now *Pseudoplasmopora gippslandica*] and reported *Favosites forbesi* Edwards & Haime [=*F. coactilis* Philip and *F.* sp.], from limestones from 'Cooper's Creek, behind Chinamen's Garden'; he also reported *F. nitida* Chapman [now *Squameofavosites nitidus*] from 'behind Cooper's Creek copper mine'. The former locality is assumed to have been the limestone lens where Evans Brothers' Quarry is situated, the latter possibly a conglomerate with limestone clasts. Subsequently, Chapman (1921) illustrated *Alveolites regularis* Chapman [=*Favosites squamuliferus stelliformis* Chapman] and identified *Pleurodictyum megastoma* McCoy from unspecified localities at Coopers Creek. Cooper (1971), obtained the zonally important *Eognathodus sulcatus* from a 13 kg sample of limestone from Evans Brothers' Quarry.

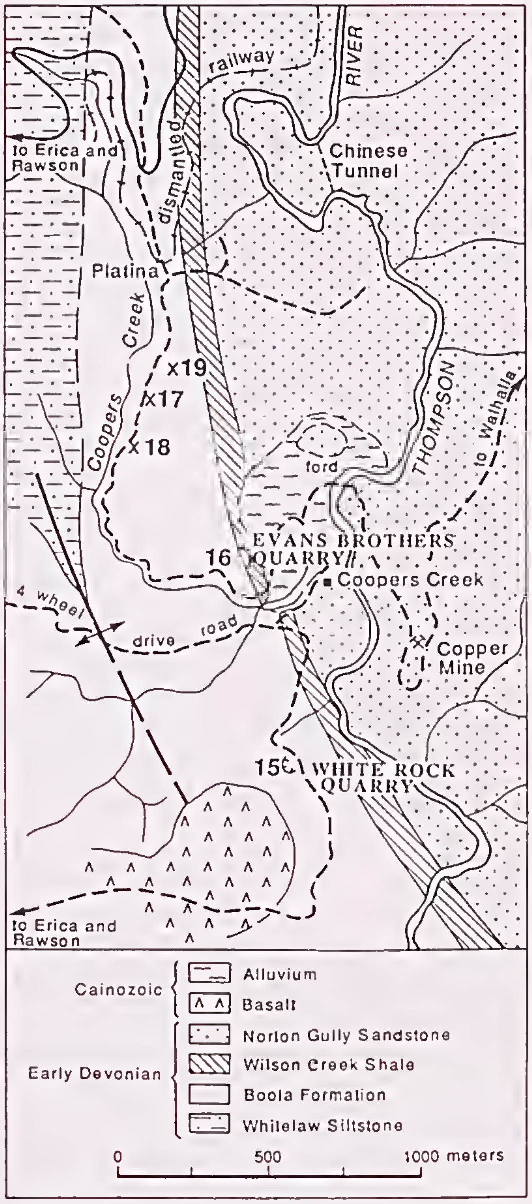


Fig. 3. Location of spot samples from Early Devonian carbonates in the Platina–Coopers Creek area, east-central Victoria. Localities are those of Thomas (1942); basemap is from Vicmap 1:25 000 topographic sheet 8122-2-2 Walhalla; formational boundaries and names are those of VandenBerg & Garratt (1976) except that, to bring nomenclature into line with subsequent usage, Coopers Creek Formation *sensu* VandenBerg & Garratt (1976) is replaced by Boola Formation *sensu* VandenBerg (1988).

SAMPLING

Approximately 1.3 tonnes of samples (5–10 kg each) were obtained from measured stratigraphic sections at the Boola and Tyers quarries, and from spot samples from other localities at Tyers, Deep Creek and Marble Creek, and in the Platina–Coopers Creek area (Figs 1–4). Samples that produced no conodonts after leaching 1.5–2 kg were then discarded; most samples proved productive at this stage and were then dissolved completely. Locations of the stratigraphic sections sampled in the Tyers–Boola area are shown in Fig. 1; positions of horizons sampled are indicated on the stratigraphic columns in Fig. 4. Between 60 and 70 kg were collected from the 'Middle Crossing' megaclast on Deep Creek and from limestone blocks in the underlying conglomerate; samples of calcareous flysch from Deep Creek below Scatabit Creek, and from the west branch of Deep Creek proved barren. Large samples were taken from both of the old 'Toongabbie marble quarries' in the Marble Creek area, about 80 kg from the lower quarry and about 40 kg from the lowest part of the upper quarry. Four of Thomas's (1942) six limestones in the Platina–Coopers Creek area were sampled; these and an isolated area of limestone spall were sampled; all produced conodonts sparingly (Table 2). Cobbles of limestone occur in conglomerates at many localities in the meridional belt extending through Coopers Creek, for example 'near the steel bridge over the Thomson River, about two miles north of its junction with Stringer's Creek' (Junner 1915, p. 289) but our attention in this belt was focussed on the main occurrences.

INTERPRETATION OF CONODONT DATA

Productivities of conodonts from the stratigraphic sections and spot samples from the Tyers–Boola area were generally much higher than for most Early Devonian horizons in south-eastern Australia (e.g. Mawson et al. 1992). This is presumably a reflection of the generally deeper water environments represented in what has been preserved of the carbonate fan in that area. Much lower productivities from most limestone bodies farther north, particularly those of the Platina–Coopers Creek area, are assumed to be connected with the generally very shallow environments represented by these clasts and megaclasts.

In the discussion which follows we have, as previously (Mawson et al. 1992), adopted Lane & Ormiston's (1979) refined the conodont zonal scheme for the Pragian. They demonstrated the utility of three intervals: a redefined zone of *Eognathodus sulcatus*, an intermediate zone of

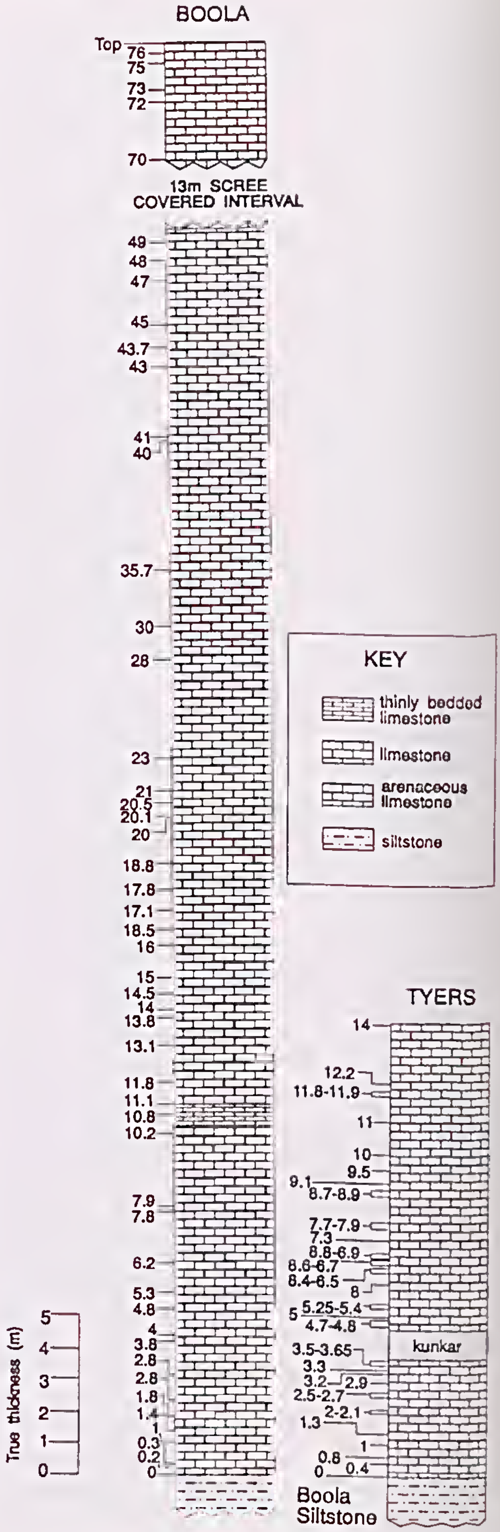


Fig. 4. Stratigraphic sections at Tyers Quarry and Boola Quarry showing horizons sampled.

E. sulcatus kindlei and, as youngest interval, an interval with *Polygnathus pireneae*. The lower boundary of the *pireneae* Zone was defined at the incoming of *P. pireneae*. Due to rarity of both *P. pireneae* and *P. trilinearis*, there may often be difficulties of recognizing the *pireneae* (and/or *P. trilinearis*) interval in the late Pragian. There is still need of an elegant sequence, rich in conodonts, where the transition *Eognathodus* to *Polygnathus* can be documented in detail.

1. Age of the Tyers–Boola carbonate fan

The stratigraphically lowest horizons producing conodonts in the Boola and old Tyers quarries (Fig. 4; Tables 1 and 2) are already *sulcatus* Zone, and not the earliest discernible interval in that zone characterized by *Eognathodus sulcatus eosulcatus* Murphy. That forms typical of the *kindlei* Zone enter low in both stratigraphic sections (7.3 m at Tyers Quarry, 7.8 m at Boola Quarry), and that simplest morphs of *E. sulcatus* are absent from both sections, suggests that much of the *sulcatus* Zone is not represented in the Tyers–Boola area.

Neither *Polygnathus pireneae* nor *P. trilinearis*, the entry of which we would take to be indicators of the *pireneae* Zone, appear in either of our stratigraphic sections. It is therefore possible that the highest parts of both sequences sampled are still within the *kindlei* Zone. Nevertheless, the occurrence of an 'early form' of *Polygnathus dehiscens* from our locality 12 at Tyers demonstrates that the uppermost part of the Coopers Creek Limestone is *dehiscens* Zone (earliest Emsian). We have therefore not exhaustively sampled the uppermost exposures of the Coopers Creek Limestone; limestones from this part of the sequence tend to be massive and yield few if any conodonts. The *pireneae* Zone could well be present but, because of the paucity of conodonts, may not be represented by its indicator species.

Rehfisch & Webb (1993) have interpreted the Coopers Creek Limestone of the Tyers–Boola area as a predominantly carbonate fan deposited, with re-working, into deep water. At least part of the overall sequence, specifically in the vicinity of Boola Quarry, can be interpreted as shallowing upwards. In the upper part of the 'BOO' section at Boola Quarry there is a change to more massive and poorly bedded limestones concurrent with a decline in conodont yield per kg; samples from massive limestones from the hilltop immediately west of the quarry proved barren. We suggest this pattern to be evidence for shallowing upwards perhaps even into a storm-dominated environment.

There is a persistent belief that the Victorian occurrences of *Monograptus thomasi* more or less equate with the *sulcatus* Zone (e.g., Garratt 1983b, p. 85; VandenBerg 1988; Jaeger 1989). For instance, VandenBerg (1988, p. 120) has concluded that '*Monograptus thomasi thomasi* Jaeger is laterally equivalent to the *Eognathodus sulcatus* Zone in the Lilydale Limestone and Coopers Creek Limestone'. In addition, he concluded that horizons represented by *M. aequabilis notoaequabilis*, occurring 'at the top of the Wilson Creek Shale and in the overlying Norton Gully Sandstone' are temporally equivalent to 'the Late Pragian *Polygnathus dehiscens*'. These conclusions were based on much field experience of relatively intractable sequences, on Philip's (1965) work on conodonts at Tyers Quarry, and on an unpublished manuscript (Carey & Bolger ms.) reporting conodonts from two calcareous horizons in the Wilson Creek Shale with an earliest Emsian (not late Pragian) combination of *Polygnathus dehiscens* and *P. pireneae.* Because much, perhaps most of the *sulcatus* Zone is not represented in the Tyers–Boola sequence, and because the sequence extends through the remainder of the Pragian into the early Emsian, from somewhere in (and perhaps high in) the *sulcatus* Zone to at least early in the *dehiscens* Zone, the one-to-one relationship between the *thomasi* and *sulcatus* intervals, as assumed by VandenBerg, cannot be maintained.

Of some interest in this regard is the report by Lenz (1989) of *M. thomasi* in association with *M. yukonensis* and *M. telleri* and his inference that *M. thomasi* is indicative of 'part of the overall *yukonensis* Zone fauna', for which Jaeger (1989) inferred a probable *kindlei* or younger age. It is therefore possible that *M. thomasi* need not have originated until a stage or more later than was once assumed by Victorian workers, i.e. approximately mid-Lochkovian (VandenBerg & Schleiger 1972, Fig. 2). The above data highlight the need for yet another quest for improved time-control through the largely detrital units of central Victoria, an exercise we recognize will not be an easy task.

2. Age of the Boola Formation

The significant shelly faunas of the Boola Formation in the Tyers–Boola area (Philip's 1962, loc. 48 and above) are restricted to the uppermost 45 m of the formation, just beneath the Coopers Creek Limestone. The age assigned to this fauna has fluctuated. Philip (1960b, 1962) at first considered the Boola Formation to be Late Ludlow in age and suggested that the boundary between it and Coopers Creek Limestone should be taken as approximating the Silurian–Devonian boundary.

Metres above base of section 'BOO'		0	0.2	0.3	1	1.4	1.9	2.4	3.3	4.2	4.4	5.3	5.8	6.7	8.2	8.3	10.6	11.1	11.4	12.2	13.3	14.1	14.3	14.8	15.3	16.2	16.8	17.3	17.9	18.8	20.1	20.2	20.7	21	21.9	24.8	25.8	31.2	34.1	34.8	36.1	36.8	37.3	50.3	52.1	52.3	53.2	53.5	53.8
Conodont taxa / Sample No.		0	0.2	0.3	1	1.4	1.8	2.6	2.8	3.8	4	4.8	5.3	6.2	7.8	7.9	10.2	10.8	11.1	11.8	13.1	13.8	14	14.5	15	16	16.5	17.1	17.8	18.6	20	20.1	20.5	21	23	28	30	40	43.7	45	47	48	49	70	72	73	75	76	Top
Belodella devonica		2				1			1					2	3	8	4					3											4			3			1		1		1	1	1				5
B. resima		4			1		1		5	2		3	2	4	9	16	1	1		1	3	4		1	17	3	4		2	2		2	2	1	1			1	1				2	1	2			1	2
B. triangularis		3								1	1			4	2	8	1				2				1							1		1		1							1						5
Coelocerodontus reduncus		1				1	1		1					2		3					2	1			2		1			1			1	1															
Pseudooneotodus beckmanni		1			1		5		12	2						2																																	
Drepanodus sp.					1	1	1	1	1	1				2	1	1					1	12		2	2	4	2							2	3				1	1			2	3	3				
Neopanderodus aequabilis		1														2						1					1																						
Panderodus recurvatus														1		6	2				1	6					1			1				1									1		1				
P. unicostatus		2	1		1	1	5	2	8	1		1	1	17	8	27	4	1	3	1	2	11		1	7	3		1		2	1		1	7	1			1		1	1	1	1		1				3
P. valgus					1		1		2	1				4	1	7	2	1			1	2			1	1			2			3	3	1	5	3			1		3		3	2	2				2
Pedavis brevicauda	I				1														1			5		1		1										1				1	5								1
	M																					1													1						1			1	1				1
Icriodus steinachensis eta morph		1																																	1	1								1					2
Icriodus spp.																							1																					1				1	1
Oulodus cf. *walliseri*	Pa																					2																		1									
	Pb	1			1											1						5		1	2		3						1												1				
	M																				1																								1				
	Sa						1								2				1			3																											
	Sb															1					1	3				1				1								1	1		2								
	Sc									1											1	3													1				1	1	3							2	
Oulodus sp.							1																																								1		
Amydrotaxis druceana	Pa				1		1		2					1	1	1						1								2					1				5	3	4	4	1		10				
	Pb																													1				1	1				2	2	3		1		7	1	1	3	
	M																					3											1												3				
	Sa	1			2																1									1					2	1			3	1					7			1	
	Sb															1														2					1	1			3	2	1			2	7				
	Sc						2	1	1		1					1					1	2								4	1				1				3	3	2				16			1	
Ancyrodelloides omus alpha morph		2					1	1	4	3	1	1	2	12	8	3	1	2	8			52			5	8	2	2			1	2			2			1				3	1				1		
Anc. omus beta morph			1										5	39	30	23		3	4			33					1	3														1							
Eognathodus sulcatus morphs		1	1		7	1	3	3	7	6		5	11	13	32	11	1		2	1	3	28		7	7	14	23	3	1	5		1		4	10			1	2	4	3	3	3	5	15	2			1
Ozarkodina excavata excavata				1		2	3	3	9	17	2	1	4	1	4	3			12			2																					2						
O. remscheidensis repetitor		1												5	1							6																											
Pandorinellina optima									1									1			1	4																											
Pand. steinhornensis miae		5		1	3	3	2	1	8	4		4	6	13	25	10	4	6	10		5	119		4	31	44	14	4		1	4	2		8	13			1	4	2	4	6	3	3	4			1	2
Unassigned elements	Pa																																								1								
	Pb	1	1	1	1	2	3	3	7	10	1	3	5	12	15	20	5	2	3		7	46	1	1	9	12	8	1	2	1				10	11	1		1	2			2	3	1	4			1	2
	M								3	5		1	2	1	4	3	1				1	3			2	2	2							2	2	1				1			1		1				
	Sa			1					1	1	1	1		1		1			2		1	3		1	3		2			1				2	2				1	1				1	1				
	Sb	2	1		1		3	1		13	3	1	1	5	6	12		1	3	1		14			3	4	2	1	1	2		1		5	2		1		1	1		4	2	1	1				2
	Sc				1	1	5	1	2	9		2	6	8	11	14	2	3	4	1	5	13			4	10	2		2	3		1	1	3	5			1		1		1	1	1	1	3			
Unassigned cones														1					1																														

Table 1. Distribution of conodont elements in section BOO through the Coopers Creek Limestone at Boola limestone quarry.

Conodont taxa		Metres above base of section 'TQ'																														TUB	Murray's Gully					Deep Ck. - Marble Ck.							Coopers Ck. - Platina				
		0-0.2	0.4	0.6	1	1.3	2-2.1	2.5-2.7	2.9	3.2	3.3	3.5-3.65	4.7-4.8	5	5.25-5.4	6	6.4-6.5	6.6-6.7	6.8-6.9	7.3	7.7-7.9	8.7-8.9	9.1	9.5	10	11	11.8	11.8-11.9	12.2	14	Top	12	7	8	9	10	11	1	3A	3C	4S	4W	5	6	15	16	17	18	19
Belodella devonica											1		1			2	1		5	3	3		3					6	2		1		3						2		4	2	77	1		3			
B. resima		2				1	2				1		5			3		2	1	1	2							4	1		3	1	4			5	2		3	2	14	5	175	4		7	1		
B. triangularis		1									1	1				2		4	1							1		6	1		1		1			1	1		1			1	9			5			2
Coelocerodontus reduncus																				4	1		1					1		1	1								2					1		1			1
Pseudooneotodus beckmanni		3					3		1		7		9			1	1	7	4	3									1								1				1					1			
Drepanodus sp.		7	1																									1					1	1		7					1	1		1		4	1		1
Neopanderodus aequabilis													2															1					1			1													
Panderodus recurvatus		1				1											1				2					1	1	2					2			2	1				1	2							
P. unicostatus		18	1	1	3	6	13	3		1	3	2	2			7	7	3	4	10	3		3			2		49	1	4	11	1	10			17	9						1	3	1	3			1
P. valgus							4	4					4			6	1	4	2	4	1		2			2		9	2		4	1	4			6	3		1	2	4	4	5	1		6		1	
Pedavis brevicauda	M																																	1															
Icriodus steinachensis eta morph														1						1			1										1																
Icriodus spp.														1				1		2													1																
Oulodus cf. *walliseri*	Pa																	2																						1									
	Pb																1											2					2			3	9			1	1	2	1						
	M																																				1				1	2							
	Sa																											1								2	2				1	3							
	Sb																																				2				2	1							
	Sc																											1									2					2							
Oulodus sp.																																1										1		2	1				
?Erika sp.																																										1							
Amydrotaxis druceana	Pa	1			2			1			1					2	3		1	1	1							2	1	1				2			2												
A.druceana (other elements)		1			1											1																		2		1													
Ancyrodelloides omus alpha morph		1									2	1	2			2		4	1	8	1		7			1		14	7	4			1			7	1					1							
Anc. omus beta morph																2		1	1	10	6		41			3		48	10	5	2			1		1	1												
Eognathodus sulcatus morphs		1			3		3	6	1		1	1	3	2		12	9	4	4	5	5		27			2		30	18	12			2		1	2	1									2			
Ozarkodina ?confluens																																							1										
O. excavata excavata		9	2		3	11	7	7			7	1	4			9	13	28	14	27	5		9					7		2						3	38		1	1	6	15	1	8	3	6	2		3
O. pseudomiae																																1																	
O. remscheidensis remscheidensis																																							5					5			4		
O. r. repetitor		2				3										1										2																				12			5
Pandorinellina optima		1				1	1						1				1						1					4					1	1								1				3	1	1?	
Pand. steinhornensis steinhornensis																																											1			3			
Pand. s. ?eosteinhornensis																																							1										
Pand. s. miae		15	1				5	4		2	2	1	10			11	10	1	2	27	4		29	1			1	62	21	1	14		2	2		37	8				1	2		2		29			5
Polygnathus dehiscens																																1																	
Unassigned elements	Pa		1					1					1			3				1																			2		1	1				1			
	Pb	9	1	1	5	4	5	3			2	1	5			17	10	22	15	31	6		23			1	1	50	4		2		2	1		12	21		2		10	16	1	1	1	13	2		3
	M	2	1		1	1	5	1					3			3	3	9	8	9	2		5					7		2						4	6		2		3	6			2	4			
	Sa	3	1		1	2	1	1								6	3	7	9	9			3					14	2					1			6		2	1		4			3				
	Sb	5	2	1	2	4	5	5		2	3	1	2	1		9	6	17	11	19	4		8				1	17	4	5	2		4			5	9		1		5	17	4	4		7	1		2
	Sc	7	1	1	1	5	4	1	1		3	1	4		1	9	7	27	16	20	6	1	9		1	2	1	22	4	7	1	1	3			5	17	1	2	2	5	21	2	6	2	10			1
Unassigned cones							1				2		3																																				

Table 2. Distribution of conodont elements in section TQ through the Coopers Creek Limestone at the old Tyers limestone quarry and from spot localities from the Tyers–Boola, Deep Creek, Marble Creek, and Platina–Coopers Creek areas.

Discovery of a terebratulid brachiopod, though generically unidentifiable, provided evidence for a Devonian age for the faunas of the uppermost Boola Formation (Philip 1962, Appendix). Subsequently, on the basis of conodonts he concluded that an 'Upper Gedinnian or early Siegenian' age [approximately late Lochkovian–early Pragian in modern parlance] was more likely for the Coopers Creek Limestone (Philip 1965). He (Philip 1965, 1968) also argued for an appreciable diastem between the Boola Formation and the Coopers Creek Limestone. This was accepted by Savage (1973) who referred the faunas of the uppermost Boola Formation to the late but not latest Lochkovian, and placed the Coopers Creek Limestone at about the middle of the Pragian. Garratt & Wright (1989) referred the faunas from the uppermost Boola Formation to their *australis* brachiopod assemblage zone to which they assigned a late Lochkovian age, approximately equivalent to an interval represented by the *pesavis* Zone and the later half of the *delta* Zone. The top of the Boola Formation for them would coincide approximately with the Lochkovian–Pragian boundary; this is a little lower than the position we advocate.

Though, locally, erosional features are apparent at the base of the Coopers Creek Limestone (Philip 1965, 1968; VandenBerg 1988; Rehfisch & Webb 1993), there are other areas, e.g. at the base of our section in Boola Quarry, where sedimentation appears to have been continuous. We are therefore of the opinion that even in areas where erosional channels may be seen at the base of the Coopers Creek Limestone that such channels need not imply a significant diastem (*contra* Philip 1965, 1968). Because the basal beds of the Coopers Creek Limestone are already within the *sulcatus* Zone, we are of the opinion that the locally highly fossiliferous uppermost beds of the Boola Formation in the Tyers–Boola area equate with some or all of the earliest part of the *sulcatus* Zone, including the brief interval characterized by *E. sulcatus eosulcatus*.

3. *Ages of limestone clasts and megaclasts*

For many years the assumption was implicit, if not in fact explicit, in most published works on the Middle Palaeozoic of east-central Victoria, that there was no great spread of age represented by the limestones of the Tyers–Boola area and the limestone clasts and megaclasts in the 'basal beds of the Walhalla Group'. Following Philip's (1965) paper on the Tyers conodonts, all were assumed to be more or less *sulcatus* Zone. Additionally, it was suggested that there was in fact 'a lateral facies change between the Wilson Creek Shale and the Coopers Creek Limestone' (VandenBerg 1988, p. 115).

Samples from the Evans Brother's Quarry limestone megaclast (loc. 16) have produced, *inter alia*, two specimens of *Eognathodus sulcatus* lambda morph, one from our sampling, one from Cooper's (1971) sampling. These indicate that this particular megaclast is no older than *kindlei* Zone. As the megaclast must have been lithified before incorporation into the base of the Wilson Creek Shale, the age of the megaclast provides a maximum age of *kindlei* Zone for the base of the Wilson Creek Shale, at least a whole zone younger than was previously assumed (VandenBerg 1988, p. 115).

Ozarkodina remscheidensis remscheidensis, a rather long-ranging form not always easily identified, has already been reported (Pickett in Holloway 1991) from a mixed sample from Marble Creek and Middle Crossing, Deep Creek (locs 3–6). We have confirmed its presence in allochthonous blocks at our localities 3, 6 and 17. A tabular clast of crinoidal limestone from the Middle Crossing, Deep Creek, locality 3 (our sample 3A), produced *O. remscheidensis remscheidensis* in association with ?*O. steinhornensis eosteinhornensis*, *O. excavata excavata*, and *O. confluens*. If presence of the last two species could be confirmed there would be evidence for a Pridoli (latest Silurian) age and evidence for carbonate sedimentation having commenced appreciably earlier in this part of Victoria than was indicated in recent syntheses (VandenBerg & Garratt 1976; VandenBerg 1988). Even so, caution would still be necessary as there is imprecision regarding time-ranges of these and closely related forms.

High precision eludes us regarding correlation of the other Marble Creek, Deep Creek and most of the Coopers Creek limestone clasts and megaclasts, largely because of the high proportion of barren samples, and the generally low yields and low diversities obtained from others (Table 2). Subjectively, the faunas obtained from the clasts and megaclasts appear to be slightly older than *sulcatus* Zone, but there is no compelling evidence. The presence of *Pand. optima* at localities 4W, 17 and 18 and *Pand. remscheidensis repetitor* at Loc. 19 indicate those blocks to be no older than *postwoschmidti* Zone. The fauna from Loc. 4W includes a specimen regarded by us as best referred to *Erika* (Fig. 14K), a genus known only from horizons of *delta* age, but additional material is needed to confirm this identification. The presence of *O. r. remscheidensis* in clasts 3A, 6, and 17 seems to indicate little possibility that they could be younger than *sulcatus* Zone.

4. *The autochthonous carbonate units at Waratah Bay*

The Waratah and Bell Point limestones of Waratah Bay, about 90 km south-southwest of Tyers (Fig. 5), are approximately the same age as the Tyers–Boola carbonate fan and the limestone megaclasts of the southern Walhalla Synclinorium. Because we believe the Waratah Bay sequences to have relevance for reconstructing the Devonian palaeogeography of east-central Victoria during Devonian times, it is appropriate to reevaluate the age of these units. Reference should be made to papers by Talent (1965, 1989), Argent (1971), Bischoff and Argent (1990) and Mawson et al. (1992) for discussion of the stratigraphy, structural setting and conodont faunas from these units. Of Argent's samples, 36 produced forms of *Eognathodus*; most others yielded forms of no great correlative significance, and numerous samples were barren. We have already (Mawson et al. 1992, p. 39) rejected the identification of *Polygnathus pireneae* from Argent's sample 163 from Teichert's (1954) Bluff Member and, by implication, evidence for identifying latest Pragian (*pireneae* Zone) at Waratah Bay. We also pointed out the danger of inferring a Lochkovian (*pesavis* Zone) interval in the lower part of the Waratah Limestone on the basis of absence of critical forms.

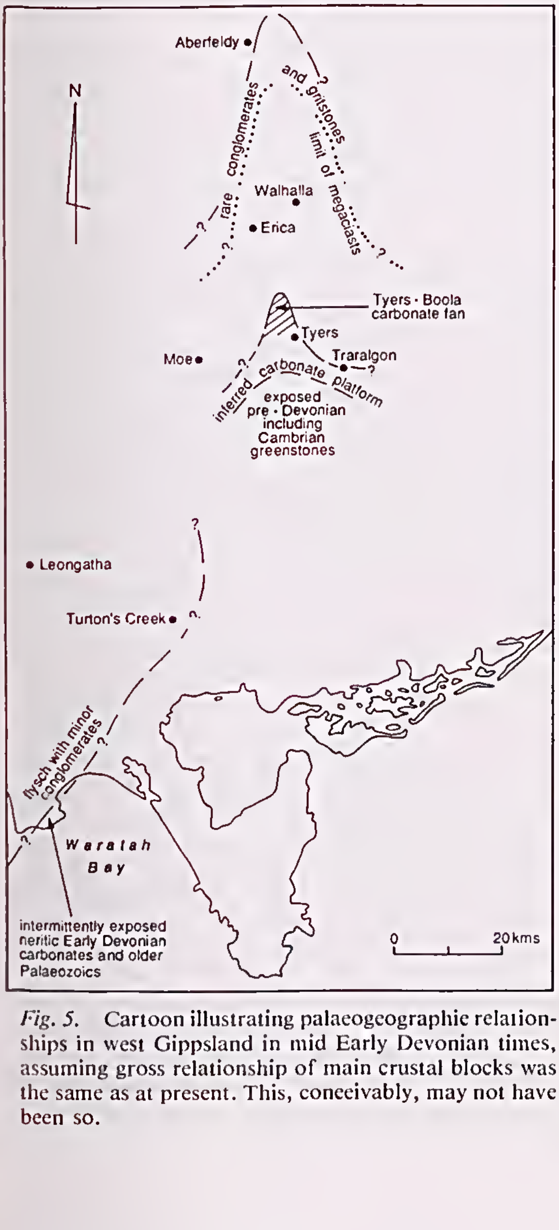

N
Aberfeldy
conglomerates
and gritstones
rare
limit of megaclasts
Walhalla
Erica
?
Tyers - Boola carbonate fan
Tyers
Moe
Traralgon
inferred carbonate platform
exposed pre - Devonian including Cambrian greenstones
Leongatha
Turton's Creek
flysch with minor conglomerates
Waratah Bay
intermittently exposed neritic Early Devonian carbonates and older Palaeozoics
0
20kms

Fig. 5. Cartoon illustrating palaeogeographic relationships in west Gippsland in mid Early Devonian times, assuming gross relationship of main crustal blocks was the same as at present. This, conceivably, may not have been so.

In inferring a *pesavis* age from what they termed the 'Lower Grinder Member' and the 'Mushroom Rock Member' of the Waratah Limestone, Bischoff & Argent (1990) based their opinion on the presence of *Pand. exigua philipi* in their sampled sections. In support of this judgment they incorrectly quoted Savage's (1977) paper on Early Devonian conodonts from the Karheen Formation of Alaska, stating that in 'material from Alaska where *P. exigua philipi* occurs together with *Kimognathus alexeii* Mashkova in the *pesavis* Zone' (Bischoff & Argent 1990: 459). In fact Savage provided data on only two localities in the Karheen Formation, both of which yielded specimens of *Pand. exigua philipi* together with *Eognathodus sulcatus* but neither of which produced specimens of *K. alexeii*. Bischoff & Argent (1990: 459) quote Savage & Gehrels (1984) as support for co-occurrence of *K. alexeii* and *Pand. e. philipi* being suggestive of 'a late *pesavis* or early *sulcatus* Zone age'. Likewise, their unreferenced report from the Garra Formation of the occurrence of *Pand. e. philipi* from within the *pesavis* Zone is not firm evidence for the lower part of the Waratah Limestone being necessarily referable to the *pesavis* Zone. In fact, the co-occurrence of *Ozarkodina eberleini* with *Pand. e. philipi* is more suggestive of assignment to the *sulcatus* Zone (Savage 1977; Klapper & Johnson 1980; Savage & Gehrels 1984).

At Grinder Point, the first forms referred to *Eognathodus sulcatus* were obtained by Bischoff & Argent (1990) from 109 m above the unconformity at the base of the Waratah Limestone (Talent 1989; Mawson et al. 1992). The interval 0–109 m was assigned by them to the *pesavis* Zone but none of the taxa in the low-diversity assemblage obtained from this interval necessarily suggests a pre-*sulcatus* age. The basal section of Waratah Limestone resting unconformably on dolomites of the Digger Island Formation west of Robins' Rocks on the shoreline (='Black Stack' of Bischoff & Argent) likewise failed to yield unequivocally pre-Pragian conodonts; we have sampled a section at Robins' Rocks with similar equivocal results. Bischoff and Argent's sections at Gair Rock and Mushroom Rock produced *E. sulcatus* in the stratigraphically lowest horizons sampled but both sections commence stratigraphically well above the lowest horizon to yield *E. sulcatus* at Grinder Point (?*c*. 20 m in the case of their Mushroom Rock section; ?*c*. 35 m in the case of their Gair Rock section). We therefore find no compelling evidence for or against horizons referable to the *pesavis* Zone at Waratah Bay.

The forms of *E. sulcatus* illustrated by Bischoff & Argent (1990) from the Waratah Limestone and the Bell Point Limestone at Waratah Bay were assigned to three of the morphs discriminated by Murphy et al. (1981): their iota, kappa and mu morphs. Few illustrations were given of the critical undersides of most specimens figured. In fact, the only illustration (Bischoff & Argent, 1990, pl. 3, fig. 1) of the lower surface of a specimen identified as *E. sulcatus* mu morph from Bell Point 71, the species critical for discriminating *kindlei* Zone, is almost identical to the lower surface of a specimen identified as *E. sulcatus* kappa morph from Gair Rock 19 (Bischoff & Argent, 1990, pl. 3, fig. 8). Until adequate documentation has been presented for other specimens identified as *E. sulcatus* mu morph, there is no compelling conodont evidence to indicate an age other than *sulcatus* Zone for either the Waratah or Bell Point limestones. Until such data become available, one must continue to rely on the incompletely documented macrofossil faunas of these units.

5. *Implications regarding palaeogeography*

All limestone bodies interpreted by us (see above) as megaclasts occur in the southern part of the Walhalla Synclinorium. Apart from the Loyola occurrences (Cooper 1973a; Mawson et al. 1992) *c*. 90 km north of Walhalla, no limestone clasts of substantial size occur farther north than loc. 27, about 15 km north-northwest of Walhalla. The general pattern of decreasing grain size of the conglomerates northwards from Tyers through the Coopers Creek and Walhalla regions, the evidence for exposed Cambrian greenstones shedding detritus into the same region (Junner 1915; Thomas 1942; VandenBerg 1988), and the presence of a large carbonate fan in the Tyers–Boola area are all consistent with existence of a land area with a carbonate platform or platforms somewhere to the south of the Tyers–Boola area (VandenBerg 1988; Webb 1991) during Early Devonian times (Fig. 5). We consider the richly fossiliferous limestone megaclasts to have been dislodged from this 'lost' carbonate platform or platforms and thus to provide evidence for a portion of the spectrum of carbonate lithologies that were formerly represented. The range of ages indicated by the Tyers–Boola carbonate fan and by the limestone megaclasts is consistent with persistence of carbonate sedimentation around this landmass during the interval from late Lochkovian through the Pragian until at least earliest Emsian times, with carbonate sedimentation having possibly commenced in the latest Silurian (Pridoli). The autochthonous shallow water Early Devonian limestones in an intermittently emergent area at Waratah Bay, discussed below, may have formed part of the same platform or been part of another platform.

The spectrum of lithologies represented by the limestone boulders and megaclasts from the Platina–Coopers Creek and Deep Creek–Marble Creek areas ranges from crinoidal limestones to limestones rich in algae, tabulate corals and stromatoporoids. Apart from a peculiar dolomitic arenite present in clasts and megaclasts at locality 1, we have not noted very shallow marine lithologies such as poorly fossiliferous dolomitic limestones, algal pisolites, or calcarenites and calcisiltites with notably low diversity brachiopod and/or bivalve faunas like those of the latest Pragian–earliest Emsian Buchan Caves Limestone to the east (Talent 1956a; Mawson et al. 1992). Nor are there lithologies such as dolomitic stromatoporoid-tabulate coral-rugosan-rich or mollusk-rich limestones corresponding to the very shallow water Pragian Lilydale Limestone to the west. It thus seems that, in general, the collapse structures responsible for the debris flows and megaclasts in the Boola, Wilson Creek and Norton Gully formations in the southern Walhalla Synclinorium did not bite into the adjacent Pridoli–Pragian carbonate platform margin with sufficient depth to supply a complete spectrum of the carbonate lithologies formerly represented around the platform.

Talent (1965) suggested that the makeup of the macro-fauna obtained from debris flows in the Liptrap Formation at Waratah Bay and from the coastline west of Cape Liptrap was consistent with derivation during late Early Devonian time from exposed Waratah Limestone. In the absence of identifiable material derived from a Bell Point Limestone source, he argued for slotting the Liptrap Formation into the erosional gap between the Waratah and Bell Point limestones; he had assumed no major lateral displacement along the Walkerville Fault. VandenBerg (1975, 1988, in

VandenBerg & Garratt 1976), by a sedimentologic argument but without constraining evidence as to age, asserted that the Liptrap Formation should be regarded as postdating the Bell Point Limestone. He rejected alignment of the Liptrap Formation with the Boola Formation [=Coopers Creek Formation of VandenBerg & Garratt 1976, p. 57], preferring to align it with the Norton Gully Sandstone. The history of movements along the Walkerville Fault still needs to be chronicled; the scale of translation between the blocks to east and west of it is not known. It is possible that juxtaposition of the tract of Liptrap Formation against the Cambrian–Devonian sequence of the 'Waratah Axis' could be an artifact of post–Early Devonian tectonics. It is also conceivable that the limestone cobbles (and their faunas) found in slumps in the Liptrap Formation were derived from a source other the Waratah Limestone or some former extension of it. Thus the precise age of the Liptrap Formation and its palaeogeographic situation during Early Devonian times need clarification.

6. *Boulder Flat: a footnote*

In dealing with the metamorphosed conodonts from Boulder Flat, eastern Victoria (Mawson et al. 1992), we drew attention to two forms we believed to be early polygnathids, *Polygnathus trilinearis*, of which we had 15 specimens, and a much narrower form of which we had only 5 specimens and which we identified as *P.* cf. *pireneae*. Material from the Tyers–Boola area demonstrates that the two forms from Boulder Flat had independent ancestry, the first being probably derived from *Eognathodus sulcatus* lambda morph, a wide form, and the second form, *E. sulcatus* mu morph, a narrow form. The lineages thus go back to at least the beginning of the *kindlei* Zone, predating development of '*Polygnathus*' discriminated from *Eognathodus* by a median carina.

EVOLUTION OF *EOGNATHODUS* AND *POLYGNATHUS*

From his studies of the conodonts from the old Tyers Limestone Quarry, Philip (1965) suggested *Eognathodus* to be derived from 'spathognathodid' (=ozarkodinan) stock. Based on the degree of constriction of the basal cavity, Klapper (1969) identified two forms of '*Spathognathodus*' *sulcatus* in faunas from Royal Creek, Nevada: an early form with a large, open basal cavity and a late form with a more restricted basal cavity. Additionally, he recognized morphological similarity between '*S.*' *sulcatus* and a younger species, '*S.*' *linearis* described by Philip from faunas from Buchan, Victoria, from what was later to be found to be a sequence spanning the *dehiscens* to *serotinus* zones (Mawson, 1987a). According to Murphy et al. (1981: 753), Klapper subsequently noted that, despite some similarity to '*S.*' *linearis*, that the forerunner to '*S.*' *sulcatus* was probably '*S.*' cf. '*S.*' *linearis* from Ikes Canyon, Nevada. It was shown to occur with *Pedavis pesavis* in samples from 136 m above the base of the McMonnigal Limestone (Klapper, 1977, fig. 4) and was subsequently illustrated as *Ozarkodina 'linearis'* (Philip) *sensu* Klapper (1977) (=*Ozarkodina pandora* Murphy et al. 1981).

Argument for the *Eognathodus* lineage arising from *Ozarkodina pandora* via a series of morphotypes (Murphy et al. 1981; Weddige 1987; Murphy 1989) is compelling. Evolution from *E. sulcatus eosulcatus* (=eta morph) to *E. sulcatus sulcatus* to *E. sulcatus juliae* (=kappa morph) to *E. sulcatus kindlei* (=lambda and mu morphs) has been carefully demonstrated (Lane & Ormiston 1979; Murphy et al. 1981). The last of this lineage, *E. sulcatus kindlei* is known to persist into and extend to close to the top of the *pireneae* Zone (Lane & Ormiston 1979).

In the collections from the Tyers and Boola quarries, *E. sulcatus* appears to be represented by two populations, one consisting of narrow forms and the other of wide forms. The narrow form of *E. sulcatus* tends to retain the 'normal' ornamentation of a parallel row of nodes on the upper surface whilst the ornamentation of the wide form can take on a variety of forms: two parallel rows of nodes, a ladder-like arrangement of horizontal ridges, an irregular arrangement of nodes on either side of a sulcus, or an irregular arrangement of nodes without a sulcus. In the wide form, the reduction in size of the basal cavity is less pronounced than in the narrow forms because of the geometry involved.

In a study of Early Devonian conodonts from Boulder Flat, Victoria, Mawson et al. (1992) argued that *Spathognathodus trilinearis* first described by Cooper (1973a) and later placed in the genus *Eognathodus* (Klapper & Johnson 1975), should be referred to the genus *Polygnathus*. Occurring in their faunas with *P. trilinearis* were five polygnathid specimens identified as *P.* cf. *pireneae*; these were noted as being very narrow forms. It would appear that these narrow polygnathids, giving rise to the *pireneae–dehiscens–nothoperbonus–inversus–serotinus* lineage, probably evolved from the narrow forms of *Eognathodus*. It is also likely that the wide forms of *Eognathodus* may have given rise to the *P. trilinearis–abyssus–*

perbonus–labiosus–pseudoserotinus lineage. This would imply that the subspecies of *P. dehiscens* proposed by Mawson (1987a) as *P. dehiscens abyssus* should, in fact, be regarded as a separate species, i.e. *P. abyssus*.

It appeared puzzling that the genus *Eognathodus* should not be represented in the interval from the *pireneae* Zone until reappearance in the *costatus* Zone (e.g. Klapper & Johnson 1980; Mawson & Talent, 1989) with the incoming of the widely reported species *E. bipennatus* (Bischoff & Ziegler). It is now argued (Mawson 1993) that the derivation of *E. bipennatus* was not from the Early Devonian eognathodid lineage but from another lineage of ozarkodinans, through *Pand. palethorpei* (Telford 1975), a species yet to be reported from the Northern Hemisphere.

SYSTEMATIC PALAEONTOLOGY

As the majority of conodonts in this study have been documented in the Catalogue of Conodonts (Ziegler 1973, 1975, 1977, 1981, 1991) or described more fully in earlier papers (e.g. Philip 1965; Wilson 1989; Mawson et al. 1992), we have, except for a single instance (*Eognathodus sulcatus* nu morph), limited our documentation to illustrations and discussion, restricting the latter to cases where study of the faunas has provided new information. Type and figured specimens are housed in the palaeontological collections of the Museum of Victoria (NMV P). Precise horizon and locality data for each sample number can be obtained by reference to Figs 6–15 and Tables 1–4.

Genus **Pedavis** Klapper & Philip, 1971

Type species. Icriodus pesavis Bischoff & Sannemann, 1958.

Discussion. Although *Pedavis latialata*, the oldest known species of *Pedavis* from the late Ludlow (Late Silurian, *latialata* Zone), and *Ped. pesavis* from the late Lochkovian (Early Devonian, *pesavis* Zone) have long been recognized as zonal forms, the biostratigraphic potential of other species of *Pedavis* was not appreciated until Murphy & Matti (1983) elucidated details of the pattern of evolution of *Pedavis*, based on Early Devonian faunas from Nevada. After erecting three new species, *Ped. biexoramus*, *Ped. breviramus*, and *Ped. brevicauda*, they hypothesized relationships for the various species of *Pedavis* then known, from *Ped. latialata* [*latialata* Zone] to *Ped. mariannae* [*kindlei* Zone] (Murphy & Matti 1983, text fig. 9). *Ped. sherryae* Lane & Ormiston from the *dehiscens* Zone is the youngest representative of the genus.

Metres above base of section 'BOO'	0.2	1	1.4	1.9	2.4	3.3	4.2	5.2	5.8	6.7	8.2	8.3	10.6	11.4	12.2	13.3	14.1
Sample numbers	0.2	1	1.4	1.8	2.6	2.8	3.8	4.8	5.3	6.2	7.8	7.9	10.2	11.1	11.8	13.1	13.8
eta morph				1		4	4	4	2	3	4	1					
theta morph		2		2		1	1	1	3	2	2	4		2			3
iota morph		3	1		2					1	10	1		10	1		14
kappa morph	1					1					6	2		1			1
lambda morph											1						3
mu morph																	1
nu morph									5	4	1	1	1	1		3	1
incomplete specimens		1			1	1		1	1	3	8	2					4

Metres above base of section 'BOO'	14.8	15.3	16.2	16.8	17.3	18.8	20.2	21	21.9	31.2	34.1	34.8	36.1	36.8	37.3	50.3	52.1	52.3	53.8
Sample numbers	14.5	15	16	16.5	17.1	18.6	20.1	21	23	40	43.7	45	47	48	49	70	72	73	Top
eta morph														1	1				
theta morph				5					1								5		
iota morph	2	2	3	2		1		2	4			2				2			1
kappa morph	1		1	1							1								
lambda morph	1	2	1	5		3		1	2	1	1	1		1	1		7	1	
mu morph					1		1												
nu morph			3	2										1					
incomplete specimens	3	3	6	8	1	1		1	2			1	2		1		4	1	

Table 3. Distribution of *Eognathodus sulcatus* morphotypes (*sensu* Murphy *et al.* 1981) through the Coopers Creek Limestone in the BOO section at Boola Quarry.

Metres above base of section 'TQ'	1	2-2.1	2.5-2.7	2.9	3.3	3.5-3.65	4.7-4.8	5	6	6.4-6.5	6.6-6.7	6.8-6.9	7.3	7.7-7.9	9.1	11	11.8-11.9	12.2	14
eta morph									6	3				1			3		
theta morph	2						2	1		1	2	2	1		2	1	7	4	6
iota morph	1		4		1	1	1		3			2	2	3	6		4	4	2
kappa morph	1	1		1											1		1		
lambda morph													1		3		4	3	5
nu morph															6		2	1	1
incomplete specimens		2	1					1	3	5	2		1	1	9	1	9	6	4

Table 4. Distribution of *Eognathodus sulcatus* morphotypes (*sensu* Murphy *et al.* 1981) through the Coopers Creek Limestone in the TQ section at Tyers Quarry.

Pedavis brevicauda Murphy & Matti

Fig. 6A–K

For synonymy see Murphy & Matti (1983).

Pedavis sp. cf. *Ped. sherryae* Lane & Ormiston.—Uyeno 1991: pl. 2, fig. 18.

Discussion. The illustrated specimens of *Ped. brevicauda* from central Nevada (Murphy & Matti, 1983, pl. 6, figs 14, 16, 17) show the angle formed by the lateral processes with the spindle to vary from 65° to 80°; for the holotype this angle is 70°. Specimens from the BOO section show a slightly greater variation: 63° to 91°. This range of variation can be illustrated with specimens recovered from one bed within the limestone at Boola Quarry, namely in BOO13.8 (Fig. 6A, D, G).

Although Murphy & Matti (1983) show the range of *Ped. brevicauda* to extend almost to the top of the *sulcatus* Zone (Murphy & Matti 1983, text fig. 9), material from the new collections from the Tyers and Boola quarries indicate it occurs in samples with *E. sulcatus* lambda and mu morphs indicative of the *kindlei* Zone. Similarly, the specimen of *Ped. brevicauda* from Solo Creek, Yukon Territory, illustrated by Fåhraeus (1971, pl. 78, figs 1–2) from his sample V-2, occurs in association with several specimens of *Eognathodus sulcatus kindlei* Lane & Ormiston (= *E. sulcatus* lambda morph of Murphy et al. 1981), further confirmation that the upper range of *Ped. brevicauda* is no lower than the *kindlei* Zone.

The specimen illustrated by Uyeno (1991) as *Pedavis* sp. cf. *sherryae* from the Michelle Formation in northwest Canada is characterized by a short, peg-like posterior process deflected laterally, a feature indicative of *Ped. brevicauda*; the posterior process of *Ped. sherryae* is much longer. Uyeno's specimen occurs with *Polygnathus dehiscens* and *Pand. steinhornensis miae* thus further extending the known range of *Ped. brevicauda* into the *dehiscens* Zone.

Genus **Icriodus** Branson & Mehl 1938

Type species. *Icriodus expansus* Branson & Mehl, 1938.

Discussion. The dearth of icriodontan elements in Early and Middle Devonian conodont faunas from eastern Australia has been discussed elsewhere (e.g. Mawson 1986, 1987a, 1987b; Mawson et al. 1988, Mawson & Talent 1989). Faunas from Tyers and Boola conform to this general pattern; only seven icriodontan elements have been recovered from the many limestone samples processed for this paper. Philip (1965) recovered just one specimen from his Tyers collections.

Icriodus steinachensis Al-Rawi eta morph Klapper & Johnson

Fig 9K–N

Icriodus bilatericrescens Ziegler.—Philip 1965: 103, pl. 9, figs 30–31.

Icriodus latericrescens Branson & Mehl.—Klapper & Philip 1971: fig. 8.

Icriodus steinachensis n. sp. Al-Rawi 1977: 55–56, pl. 5, figs 42–43.

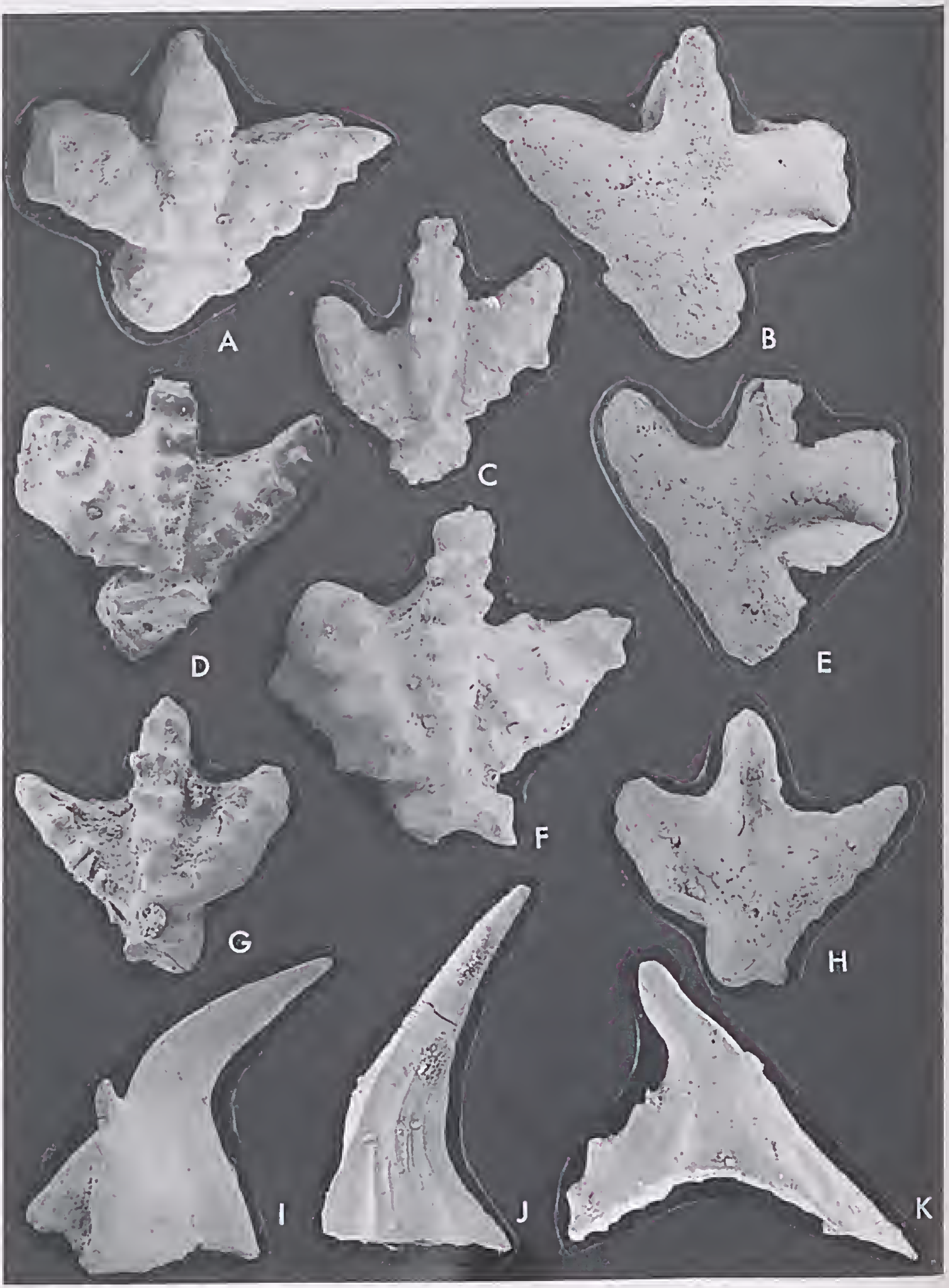
Icriodus steinachensis Al-Rawi eta morphotype.—Klapper & Johnson 1980: pl. 2, figs 25–27.

Icriodus steinachensis Al-Rawi eta morph Klapper & Johnson.—Murphy & Matti 1983: 58–59, pl. 5, fig. 36.

Icriodus steinachensis Al-Rawi eta morphotype.—Chlupac et al. 1985: pl. 2, figs 13–16.

Icriodus steinachensis Al-Rawi eta morphotype.—Schönlaub 1985: pl. 3, fig. 3.

Icriodus steinachensis Al-Rawi.—Mawson et al. 1988: table 7.


A
B
C
D
E
F
G
H
I
J
K

Discussion. As pointed out by Klapper & Johnson (1980: 407) and Murphy and Matti (1983: 58–59), the position of the widest part of the spindle of *I. steinachensis* enables discrimination of two morphotypes: eta and beta. Specimens from the Boola and Tyers quarries (herein and Philip 1965) are assigned to the eta morph because of the typical lenticular outline of the spindle with the widest part of the spindle placed centrally, and the angle of the posterior lateral process to the spindle falling within the range of 'less than 90° to 110°'. Although Klapper & Johnson (1980) indicate *I. steinachensis* eta morph to be restricted to the *pesavis* Zone and *I. steinachensis* beta morph to range through the *sulcatus* and *kindlei* zones, subsequent work on central Nevada material by Murphy & Matti (1983) shows the eta morph to appear first in the middle *delta* Zone and occur in relative abundance through to early in the *kindlei* Zone. Similarly, with material from the Lochkovian and Pragian of the Barrandian and the Carnic Alps, Chlupac et al. (1985, fig. 17) show the first appearance of *I. steinachensis* eta morph to precede the incoming of *I. steinachensis* beta morph.

Four specimens of *I. steinachensis* eta morph and two specimens of *E. sulcatus* have been identified from limestones collected and processed by G. Dongal from what is almost certainly an allochthonous block on Limestone Creek a tributary of the Pigna Barney River 49 km north-northwest of Gloucester, N.S.W. This is the first report of limestones of Pragian age from the Tamworth Belt. A specimen of *I. steinachensis* has also been reported from Martin's Well, north Queensland (Mawson et al. 1988).

Amydrotaxis Klapper & Murphy, 1980

Type species. Amydrotaxis johnsoni (Klapper, 1969).

Discussion. Four species are presently included in this genus: *Amydrotaxis johnsoni* (Klapper), *Amy. sexidentata* (Murphy & Matti), *Amy. corniculans* Mawson, *Amy. druceana* (Pickett). The last is shown to occur in horizons of *kindlei* age in samples from the Boola and Tyers quarries, and in horizons of *pireneae* age in samples from Boulder Flat, Victoria, where it occurs with *P.* cf. *pireneae* and *P. trilinearis*. (Mawson et al. 1992). The range of the genus is now taken to be from late in the *postwoschmidti* Zone to somewhere within the *pireneae* Zone.

Amydrotaxis druceana (Pickett)

Fig. 10A–N

For synonymy see Pickett (1980).

Amydrotaxis druceana (Pickett 1980).—Bischoff & Argent 1990: 453–454, pl. 1, figs 1–29.

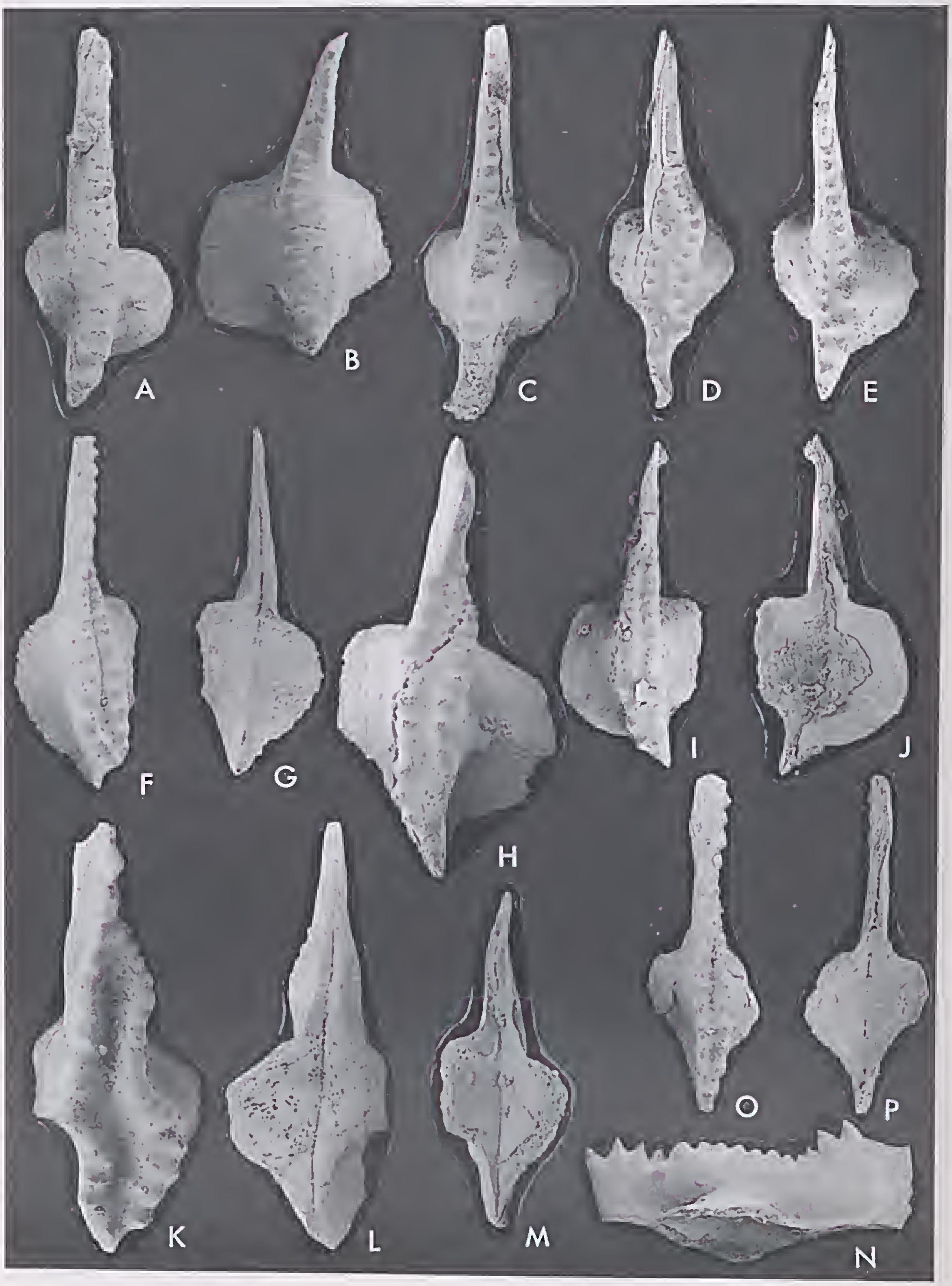
Discussion. Species of *Amydrotaxis* are discriminated primarily on the basis of the Pa element, especially the outline of the basal cavity and the profile of the blade in lateral view (Klapper & Murphy 1980; Pickett 1980; Murphy & Matti 1983; Mawson 1986). *Amy. druceana* with its asymmetrical, widely flaring basal cavity and with its pronounced tendency to fuse the denticles along the blade, appears to be youngest representative of the genus occurring in faunas of *kindlei* age in the Boola and Tyers quarries sections. From faunas derived from the Boomerang Tank Limestone and the Rookery Limestone, members of the Meryula Formation near Cobar, New South Wales, Pickett (1980) discriminated all elements of the *Amy. druceana* apparatus in sequences of *pesavis* age; these he also recognised in faunas described by Druce (1970) from the Garra Limestone now known to be of *pesavis-sulcatus* age (Wilson 1989). Collections from the Boola and Tyers quarries show the species to occur as well in the *sulcatus* and *kindlei* zones. From limestones of *sulcatus* and probable *kindlei* age from Waratah Bay, Victoria, Bischoff & Argent (1990) illustrated various elements of *Amy. druceana*.

Ancyrodelloides Bischoff & Sannemann, 1958

Type species. Ancyrodelloides trigonicus Bischoff & Sannemann, 1958.

Original diagnosis (German). 'Compound conodonts consisting of a denticulated free blade and an arrow-shaped platform with two anterior lobes, on which occasionally one further lobe can be developed, and a pointed posterior lobe. The oral surface of the platform is smooth, except for the fixed blade and median carinae on the lobes.

Fig. 6. A–K, *Pedavis brevicauda* Murphy & Matti. A, B, NMV P143030, I element upper and lower views respectively, ×45, BOO13.8. C, NMV P143031, I element upper view, ×45, BOO1. D, E, NMV P143032, I element upper and lower views respectively, ×45, BOO13.8. F, NMV P143033, I element upper view, ×60, BOO13.8. G, H, NMV P143034, I element upper and lower views respectively, ×45, BOO13.8. I, NMV P143035, M_{2b} element lateral view, ×60, BOO72. J, NMV P143036, M_{2c} element lateral view, ×45, BOO11.1. K, NMV P143037, M_{2a} element, ×75, Loc. 9.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A small basal cavity is on the aboral surface in mature specimens.' (Ziegler 1991)

Amended diagnosis (Murphy and Matti, 1983). 'A polygnathid genus with a well-developed, shelf-like platform, with or without lateral processes and with a basal cavity that is more restricted than the platform *except in the most primitive forms*' (italics ours).

Discussion. Klapper (in Ziegler 1991) accepts Murphy & Matti's (1983) argument that the genus *Ancyrodelloides* evolved from *Ozarkodina remscheidensis* (Murphy & Matti 1983, Figs 3, 4) with the first representative of the genus, *A. omus*, making its appearance late in the *eurekaensis* Zone. New collections from the Tyers and Boola quarries contain large numbers of specimens that are construed as being conspecific with *A. omus*. As they occur in samples with *Eognathodus sulcatus* and *E. s. kindlei* (= lambda and mu morphs), the range of *Ancyrodelloides* is extended from its previously known latest occurrence in the *pesavis* Zone (Klapper, in Ziegler 1991) through the *sulcatus* Zone and into the *kindlei* Zone.

Ancyrodelloides omus Murphy & Matti

For synonymy see Klapper (in Ziegler, 1991).

Discussion. There is some doubt as to generic classification of this species. According to Murphy & Matti (1983), *A. omus* differs from other species of *Ancyrodelloides* in having an unconstricted basal cavity and flattened, shouldered platform lobes that later develop tubercles on the lobes. They argue that, as the genus evolved, the basal cavity of the younger species of *Ancyrodelloides* (Murphy & Matti 1983, text fig. 5) became more constricted and tubercles were developed on the platform shoulders. The grounds Murphy & Matti (1983, p. 13–14) give for referring *A. omus* to *Ancyrodelloides* rather than *Ozarkodina* are fourfold: '1) phylogenetic interpretation of the taxa, 2) the similarity of the basal cavity and groove, 3) the appearance of a distinctive type of (O) element (= Pb element) which is apparently shared by all *Ancyrodelloides* (P) elements (= Pa elements), and 4) specimens with intermediate morphologies between several of the taxa'. Considering the first and second points, material from Tyers and Boola quarries shows that because of their co-occurrence with numerous specimens of *E. sulcatus* this form, with a wide, open ozarkodinan-type basal cavity, persisted through to at least the *kindlei* Zone. Strangely, no distinctive Pb elements with expanded basal cavity and shouldered blade have been recovered from the Victorian faunas. The few specimens recovered from the Copenhagen Canyon sections, central Nevada, that are intermediate between *O. remscheidensis, A. omus* alpha and *A. omus* beta were not illustrated (Murphy & Matti 1983); no comparison can therefore be made. It could be that this species, with its open basal cavity, is either a persistent primitive feature of *Ancyrodelloides* or that the species might be better placed in *Ozarkodina*.

The stratigraphic range of *O. omus* is not well known. Murphy & Matti (1983) considered its occurrence in Nevada (Murphy & Matti 1983), Germany (Bischoff & Sannemann 1958) and Spain (Bultynck 1971) and showed *O. omus* alpha morph to make its first appearance at the base of the *delta* Zone with *O. omus* beta appearing slightly higher in the section; neither extends into the middle of the *delta* Zone (Murphy & Matti 1983, text fig. 4). Chlupac et al. (1985, fig. 17) indicated that *A. omus* first appeared in the late early Lochkovian and ranged through to early late Pragian in conodont faunas from the Barrandian and the Carnic Alps. Klapper & Johnson (1980) included some specimens illustrated by Philip (1965, pl. 10, figs 5–7) in *O. carlsi* Boersma. In Vol. V of the Catalogue of Conodonts, these were transferred to *Anc. omus* (Klapper in Ziegler 1991). If this re-assignment is accepted, *Anc. omus* has a stratigraphic range from the *delta* Zone into the *kindlei* Zone and the range of the genus *Ancyrodelloides* is from highest *eurekaensis/postwoschmidti* Zone at least to somewhere within the *kindlei* Zone.

Murphy & Matti (1983) differentiated two morphs of *A. omus*: an alpha morph with smooth platform lobes and a beta morph with a tubercle on the platform lobes. In the new collections from

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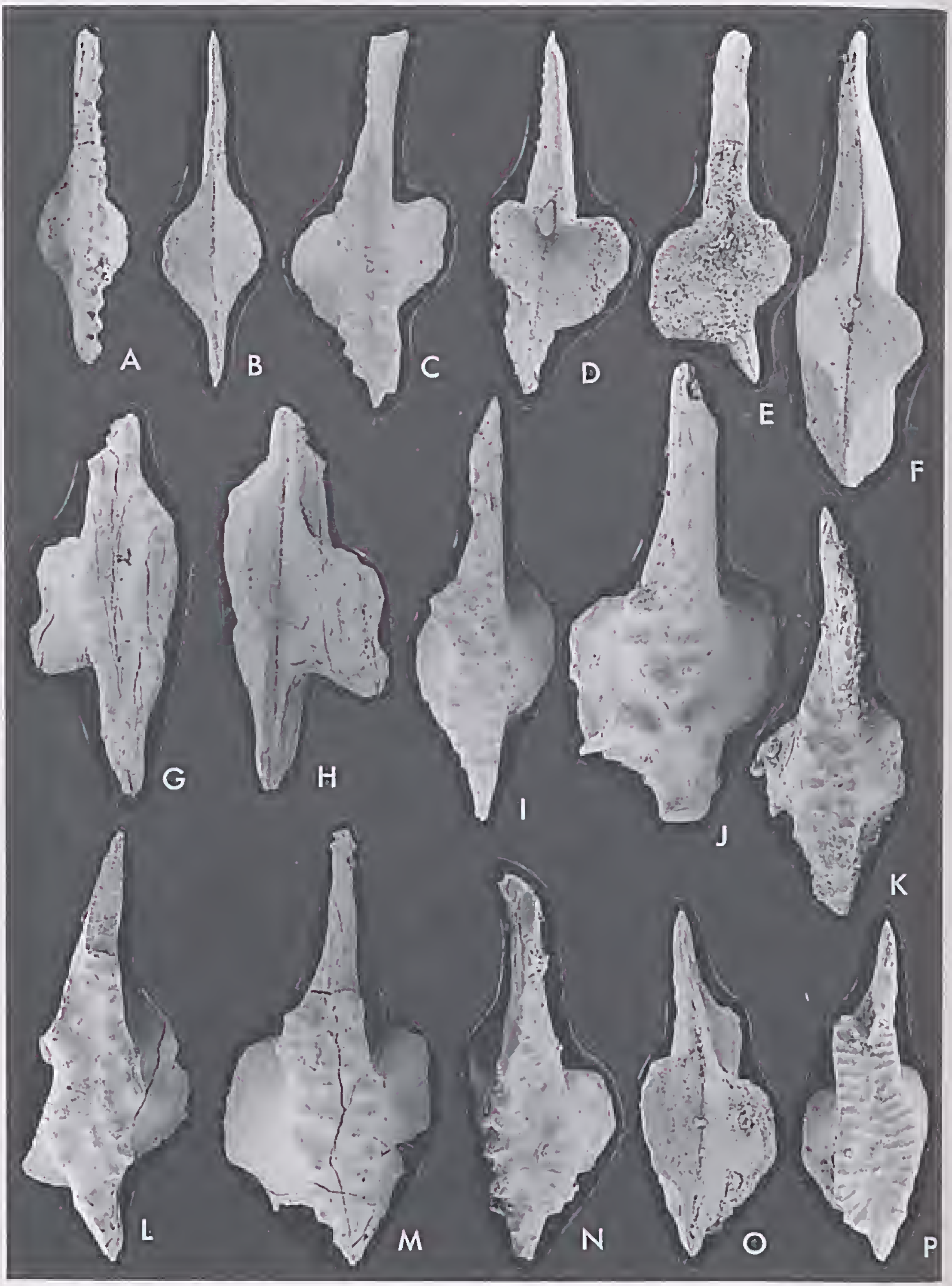
Fig. 7. A–N, *Eognathodus sulcatus* Philip 1965, all Pa elements. A–C, eta morphs. A, NMV P143038, upper view, ×45, BOO2.8. B, NMV P143039, upper view, ×45, TQ9.1. C, NMV P143040, upper view, ×60, BOO4.8. D, E, theta morphs. D, NMV P143041, upper view, ×30, BOO5.3. E, NMV P143042, upper view, ×45, BOO1.8. F–H iota morphs. F, G, NMV P143043, upper and lower views respectively, ×60, BOO23. H, NMV P143044, upper view, ×45, BOO11.1. I, J, NMV P143045, iota transitional to kappa morph, upper and lower views respectively, ×30, BOO1.4. K–P, kappa morphs. K, L, NMV P143046, upper and lower views respectively, ×45, BOO13.8. M, N, NMV P143047, lower and lateral views respectively, ×45, BOO11.1. O, P, NMV P143048, upper and lower views respectively, ×75, BOO21.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the Coopers Creek Limestone, a number of specimens have been found with a ridge connecting the tubercle to the blade (e.g. Fig. 12F–N); these have been included with the beta morph.

alpha morph

Fig. 11H–L

Discussion. The large number of specimens of *O. omus* with smooth platform lobes showing a tendency, with the onset of maturity, for a thickening or parapet to build up on the upper surface of the platform lobes (Fig. 11H). The parapet is clearly visible in one of the specimens illustrated by Philip (1965, pl. 10, fig. 10).

beta morph

Fig. 12A–N

Discussion. In many specimens from Tyers and Boola quarries, the tubercle on the platform lobe is connected by a ridge to the main row of blade denticles. Measuring the length of a sample of both populations showed the average length of the 'ridged' specimens to be 1.07 mm compared to 1.24 mm for 'tuberculate' specimens. This may be related to the stage of growth; the 'ridged' form is here considered to fall within beta morph. As the average length of the smooth-lobed specimens is very close to that of 'ridged' specimens, 1.05 mm, it seems unlikely that all smooth-lobed specimens would eventually develop ridges and/or tubercles, particularly as specimens of the smooth-lobed form have been obtained up to 1.5 mm in length.

Genus **Eognathodus** Philip 1965

Type species. *Eognathodus sulcatus* Philip 1965.

Discussion. At the time of the publication of the Catalogue of Conodonts Part III (Ziegler 1977), this genus included only four species: *E. sulcatus*, *E. secus*, *E. bipennatus* and *E. trilinearis*. The last of these, *E. trilinearis* (Cooper 1973a) was recently reassigned to the genus *Polygnathus* (Mawson et al. 1992). Topotype material of *E. sulcatus* and *E. secus* obtained during the present investigation suggests they are best regarded as synonyms, *E. secus* being most likely a gerontic form of one of the morphs of the highly variable *E. sulcatus*. Elsewhere (Mawson 1993) the species *bipennatus* has been assigned to a new genus.

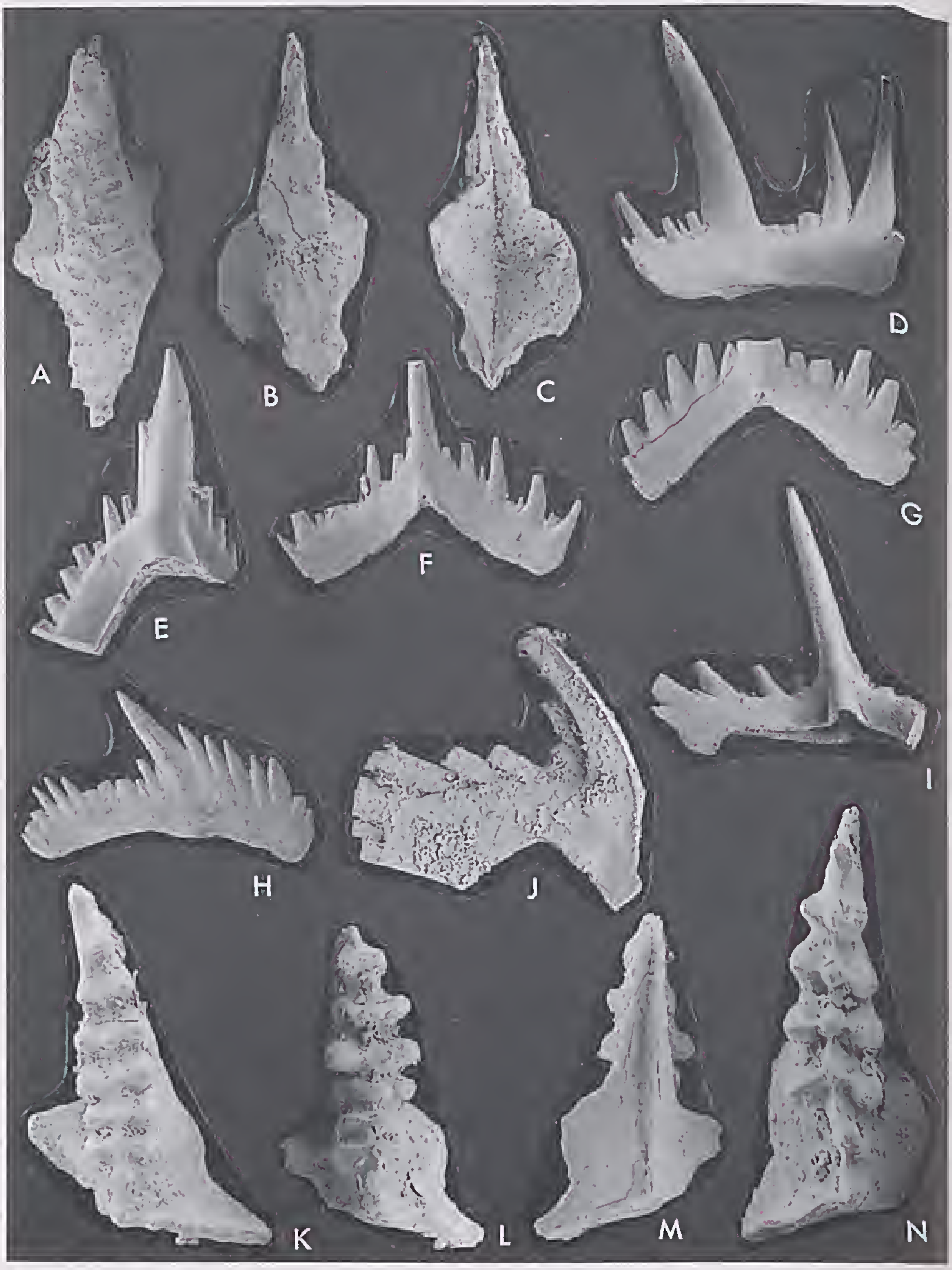
Eognathodus sulcatus Philip

Figs 7A–N, 8O–P, 9A–I

For synonymy see Murphy, Matti and Walliser 1981.
Eognathodus sulcatus Philip 1965.—Bischoff & Argent 1990: 454–456, pl. 2, figs 1–31, pl. 3, figs 1–13, 15–19.
Polygnathus pireneae Boersma 1974a.—Bischoff & Argent 1990: 459, pl. 3, fig. 14.

Discussion. The conodont fauna from the Tyers limestone quarry, from which *E. sulcatus* was first described, was extracted from a 20 kg bulk sample made up of various lithologies exposed in the quarry (Philip 1965). The specimen chosen by Philip (1965) as the holotype is a large specimen, 1.8 mm in length; other specimens illustrated by him are much smaller: 1.05 mm and 1.2 mm. Few, if indeed any, specimens that can closely be compared with the holotype of *E. sulcatus* have been reported globally, but many that are obviously conspecific with Philip's paratypes of this species are widely distributed (for example, North America: Klapper 1969, Fåhraeus 1971, Klapper 1977, Murphy et al. 1981, Savage 1977, Savage et al. 1977, Savage & Gehrels 1984, Lane & Ormiston 1979, Murphy 1989; Europe: Al-Rawi 1977, Murphy et al. 1981, Schönlaub 1985, Weddige 1987; Asia: Wang et al. 1979). Because justified concern regarding the relative stratigraphic position of the holotype of *E. sulcatus* and its paratypes has been voiced (e.g. Murphy 1989, and at meetings of the Subcommission on Devonian Stratigraphy), systematic bed-by-bed collection of sections at the Tyers and Boola limestone quarries (Fig. 4) was carried out. Over four hundred specimens of the various morphs of *E. sulcatus* were recovered from the two sections (Tables 1 and 2); these are classified according to the morphs of Murphy et al. (1981) (Tables 3 and 4). From study of both the upper and lower surfaces of the specimens, the following observations can be made:

Fig. 8. A–P, *Eognathodus sulcatus* Philip 1965, all Pa elements. A–D, lambda morphs. A, B, NMV P143049, upper and lower views respectively, ×75, BOO13.8. C, D, NMV P143050, upper and lower views respectively, ×30, BOO13.8, E–H, mu morphs. E, NMV P143051, lower view, ×30, TQ7.7–7.9. F, NMV P143052, lower view ×60, BOO73. G, H, NMV P143053, upper and lower views respectively, ×45, BOO20.1. I, early nu morph, NMV P143054, upper view, ×45, BOO6.2. J–P, nu morphs. J, NMV P143055, upper view, ×45, BOO5.3. K, NMV P143056, upper view, ×30, BOO5.3. L, NMV P143057, upper view, ×45, BOO7.8. M, NMV P143058, upper view, ×45, TQ11.8–11.9. N, NMV P143059, upper view, ×30, BOO48. O, P, NMV P143060, lower and upper views respectively, ×45, BOO13.1.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1. The incoming of lambda and mu morphs occurs 7.3 m and 7.8 m above the base of the Tyers and Boola sections respectively; these levels are therefore taken to indicate the base of the *kindlei* Zone.
2. *E. sulcatus* is a very variable species. Murphy et al. (1981) discriminated 6 morphs: eta, theta, iota, kappa, lambda and mu. A seventh morph (herein referred to as the nu morph) makes its entry at 9.1 m and 5.5 m above the base of the Tyers and Boola sections respectively. The new morph is introduced to encompass the novelties of upper surface ornamentation that can be observed in the populations of *E. sulcatus* from the Tyers–Boola area. The two specimens identified by Philip (1965) as *E. secus* are best seen as belonging to this morph (see below) as their irregular upper surface ornamentation comes within its range of variation.
3. Whereas there is a general tendency for the basal cavity of *E. sulcatus* to decrease in size with time: from *E. sulcatus sulcatus* to *E. sulcatus juliae* to *E. sulcatus kindlei*, *sensu* Lane & Ormiston (1979) [or *E. sulcatus* eta to kappa to mu morphs *sensu* Murphy et al. (1981)], the populations appear to contain two main forms: a narrow form and a wide form. The narrow form tends to retain the 'normal' ornamentation of a parallel row of nodes on the upper surface whereas the ornamentation of the wide form can be expressed in various ways (see immediately below).

Eognathodus sulcatus nu morph

P element

Figs 8I–P, 9A–C

Eognathodus secus sp. nov.—Philip 1965: 100–101, pl. 10, figs 22–23.
Eognathodus sp.—Philip 1965: 102, pl. 10, fig. 19.

Diagnosis. The *sulcatus* nu morph is characterized by a relatively wide basal cavity and variable ornamentation of the blade ranging from parallel rows of variably sized nodes, a ladder-like arrangement of horizontal ridges, an irregular arrangement of nodes on either side of a sulcus, or an irregular arrangement of nodes without a sulcus but commonly with nodes in addition to the normal two rows. The *sulcatus* nu morph differs from eta morph in that the denticle pattern extends from the central part of the blade to the posterior end.

Material. 33 specimens from 15 horizons.

Discussion. In the Boola Quarry section, the *E. sulcatus* nu morph appears high in the *sulcatus* Zone, 2.5 m above the first appearance of the *E. sulcatus* lambda morph (base of the *kindlei* Zone). In the Tyers Quarry section, the *E. sulcatus* nu morph first appears just 1.8 m above the base of the *kindlei* Zone. As the Mill Canyon and Rabbit Hill Limestone sections investigated by Murphy et al. (1981) did not extend far into the *kindlei* Zone, it is not surprising that examples of this morph were not encountered there.

Genus **Pandorinellina** Müller & Müller, 1957

Type species. *Pandorina insita* Stauffer, 1940.

Discussion. The distinction between the genera *Pandorinellina* and *Ozarkodina* is made on the basis of the Sa element. The rarity of Sa elements in the faunas from Boola and Tyers quarries makes differentiation of the two problematic; conventional assignment is therefore followed.

Pandorinellina steinhornensis miae (Bultynck)

Fig. 11A–G

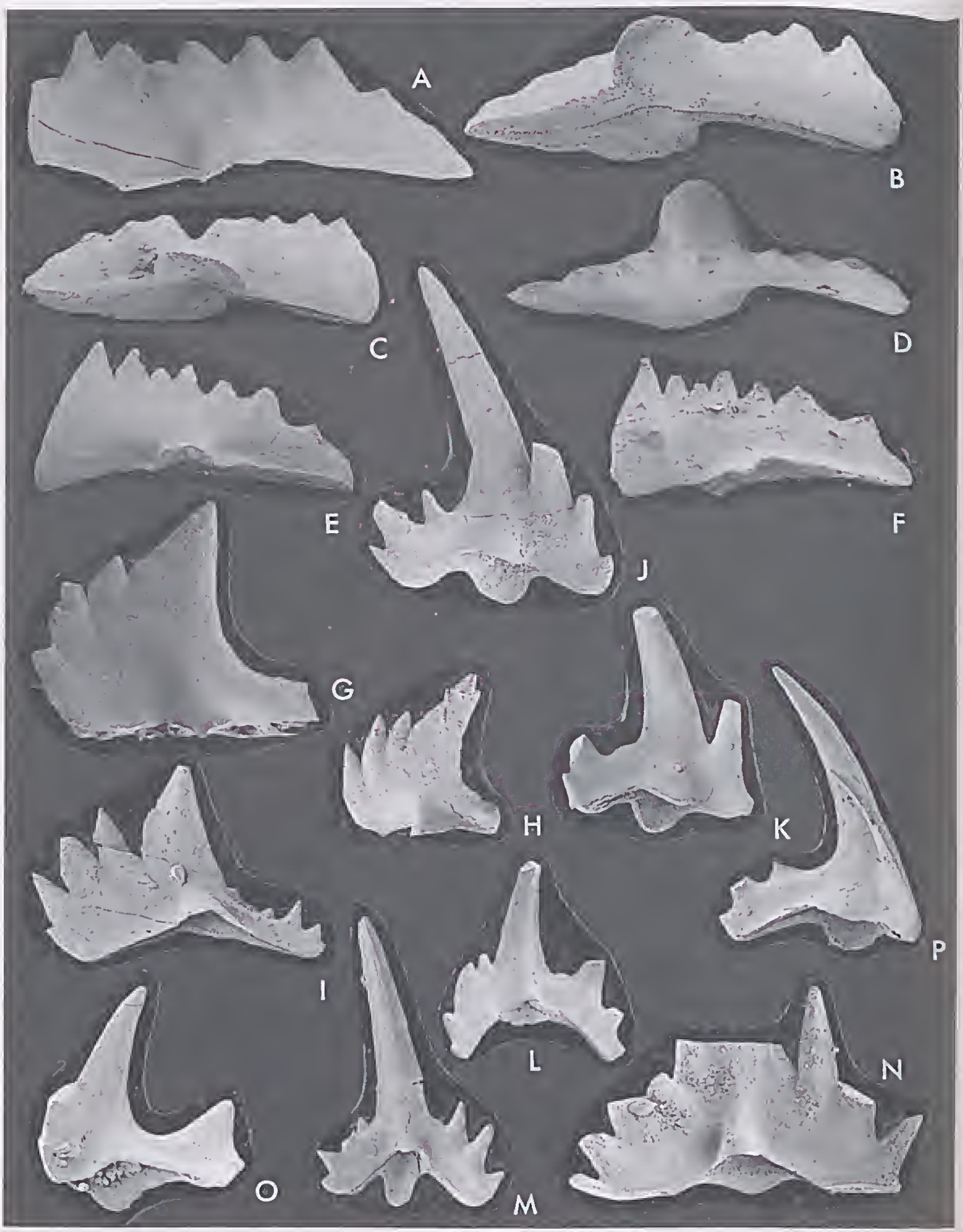
Type species. *Spathognathodus steinhornensis miae* Bultynck, 1971.

For synonymy see Klapper & Johnson (1980).

Pandorinellina steinhornensis praeoptima (Mashkova) *sensu* Lane & Ormiston 1979.—Uyeno 1991, pl. 1, fig. 19.

Discussion. The numerous specimens of *Pand. s. miae* from the Tyers and Boola quarries, exhibit the main features documented by Bultynck (1971) from the type locality in the Sierra de Guadarrama, Spain: a restricted asymmetrical basal cavity positioned slightly posterior of centre; curvature of the

Fig. 9. A–I, *Eognathodus sulcatus* Philip 1965. A–C, nu morphs. A, NMV P143061, upper view, ×45, TQ9.1. B, C, NMV P143062, upper and lower views respectively, ×45, TQ9.1. D, NMV PO143063, Sc element, lateral view, ×75, BOO3.8. E, NMV P143064, M element, lateral view, ×45, BOO13.1. F, G, Sa elements. F, NMV P143065, lateral view, ×60, Loc. 8. G, NMV P143066, lateral view, ×60, BOO23. H, Pb element, NMV P143067, lateral view, ×45, BOO23. I, Sb element, NMV P143068, lateral view, ×60, BOO/0. J, unassigned Pb element, NMV P143069, lateral view, ×60, TQ6. K–N, *Icriodus steinachensis* Al-Rawi 1977 eta morph Klapper & Johnson 1980, all I elements. K, L, NMV P143070, upper view, ×60, TQ9.1. L, M, NMV P 143071, upper and lower views respectively, ×60, BOO23. N, NMV P143072, upper view, ×90, BOO top.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blade posterior of the basal cavity; and triangular denticles arranged with a prominent one above the basal cavity as well as a few prominent denticles towards the anterior of the blade.

Specimens from the type locality, however, are from the *dehiscens* Zone whereas those from the Tyers–Boola area are of *sulcatus-kindlei* age. Most other reports of *Pand. s. miae*, for example from Morocco (Bultynck & Hollard 1980), east-central Alaska (Lane & Ormiston 1979) and Central Asia (Mashkova 1978) are from the *dehiscens* Zone. In the Oberbuchach II section in the Carnic Alps (Schönlaub 1985) *Pand. s. miae* makes its appearance prior to the entry of *P. dehiscens* and could possibly have commenced within the *pireneae* Zone.

Genus **Polygnathus** Hinde, 1879

Type species. *Polygnathus dubius* Hinde, 1879.

Discussion. For discussion regarding the derivation of the genus via *Eognathodus*, see Klapper & Philip (1972), Klapper & Johnson (1975), Cooper (1973a), and Mawson et al. (1992), and direct from *Ozarkodina* see Lane & Ormiston (1979) and Sweet (1988). Material from the Boola and Tyers quarries strengthens the case for the derivation via *Eognathodus*: two forms of *E. sulcatus*, a narrow and wide form, may have given rise to *P. pireneae* and *P. trilinearis* respectively.

Polygnathus dehiscens dehiscens Philip & Jackson

Fig. 16F–K

For synonymy see Mawson (1987a) and Uyeno (1990).

Polygnathus dehiscens Philip & Jackson.—Yolkin et al. 1989: p. 238, pl. 2, figs 3–4.

Polygnathus dehiscens dehiscens Philip & Jackson.—Uyeno: p. 82–83, pl. 9, figs 1–4; pl. 17, figs 1, 2; pl. 19, figs 1–4.

Polygnathus dehiscens dehiscens Philip & Jackson.—Mawson et al. 1992: fig. 7I–K.

Discussion. A single specimen of a juvenile *P. dehiscens* was obtained among a sparse fauna from Loc. 12 from limestones very high in the Coopers Creek Limestone on the left bank of the Tyers River (Fig. 1). With it occurred a specimen of *Ozarkodina pseudomiae*, known to arise in the *pireneae* Zone and occur commonly in faunas of *dehiscens* age (Mawson et al. 1992). The presence of *P. dehiscens* in the fauna from Loc. 12 confirms that carbonate sedimentation continued in the Tyers–Boola area until at least early in the *dehiscens* Zone (cf. Yolkin et al. 1989). Because of some uncertainty voiced to us by a colleague regarding the lower surface of the type specimen of *P. dehiscens*, it was borrowed from the collections of the Geology Department of the University of New England for examination and photography. The micrographs taken by a scanning electron microscope proved that what was thought to be basal filling attached to the under surface of the type, was in fact a moon-shaped breakage in the basal cavity (Fig. 16H, J, K).

LOCALITY REGISTER

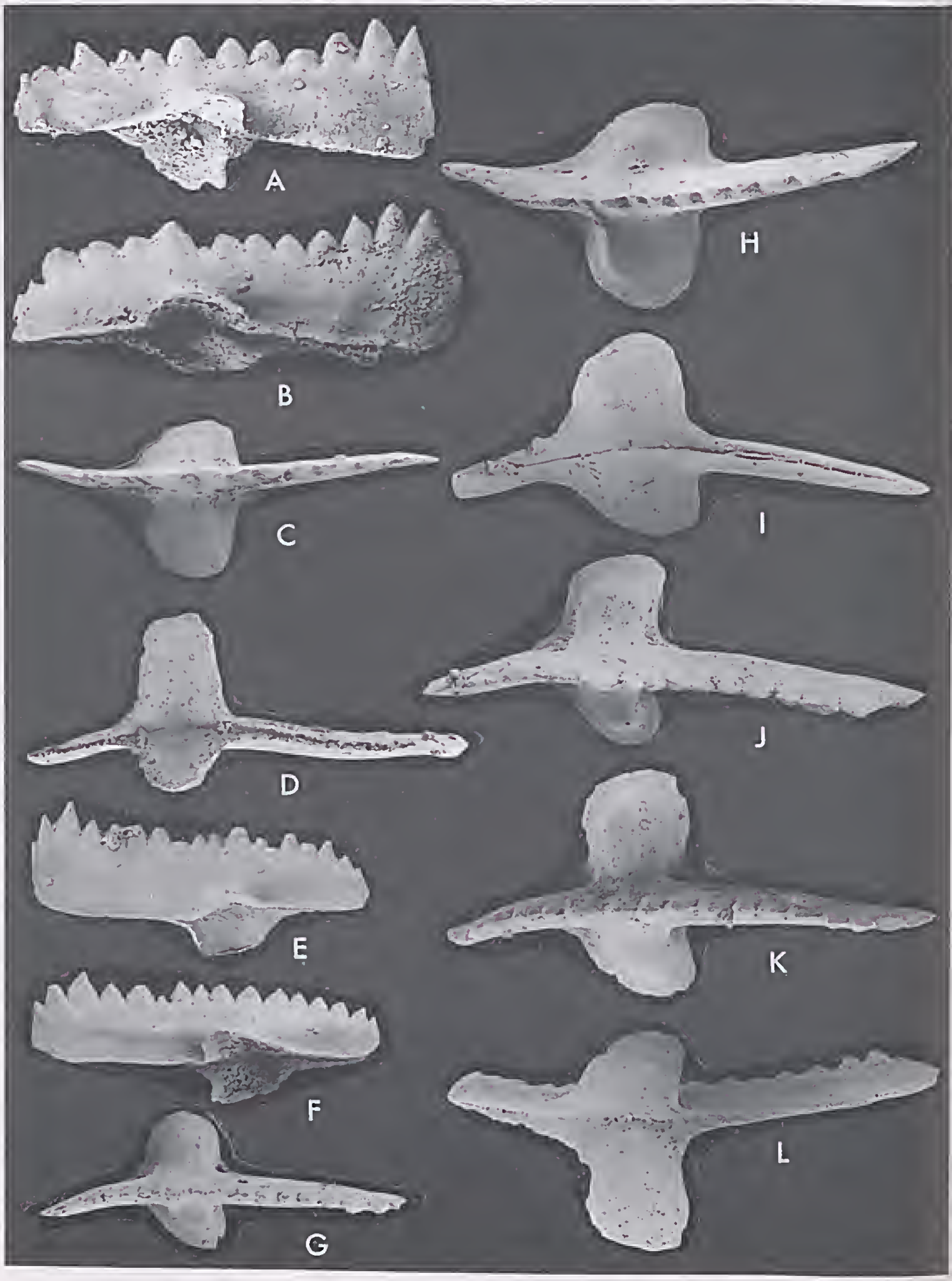
BOO—Section in Boola limestone quarry (Figs 1 and 4) sampled June 1986, commencing in what was then the lower quarry, at the conformable boundary between siltstones of the Boola Formation and limestones of the Coopers Creek Limestone. The quarry has been considerably enlarged since 1986.

TQ—Bed-by-bed sampling, January 1992, across the face of the old Tyers limestone quarry commencing with the lowest limestone exposed in a re-entrant beside the access road at the northern end of the quarry (Figs 1 and 4).

Spot localities

1. A debris flow exposed in the bed of the west (right) branch of Deep Creek. This is the occurrence reported by Baragwanath (1925, pp. 23 and 39, note 19) as 'Small lenticles of highly fossiliferous limestone ranging in size from 1 foot by 3 feet to 6 feet by 20 feet' 'associated with conglomerate up

Fig. 10. A–P, *Amydrotaxis druceana* (Pickett 1980). A–F, All Pa elements. A, NMV P143073, lateral view, ×60, BOO72. B, NMV P143174, lateral view tilted to show basal cavity, ×45, BOO48. C, NMV P143075, lateral view, ×45, BOO28. D, NMV P143076, upper view, ×60, BOO47. E, NMV P143077, lateral view, ×30, TQ/0. F, NMV P143078, lateral view, ×90, BOO18.6. G, H, Pb elements. G, NMV P143079, lateral view, ×60, BOO72. H, NMV P143080, lateral view, ×60, BOO47, I, ?Pb element, NMV P 143081, lateral view, ×60, BOO72, J, L–N, Sa elements. J, NMV P143082, lateral view, ×60, BOO72. L, NMV P143084, lateral view, ×60, BOO72. M, NMV P143085, lateral view, ×60, BOO72. N, NMV P143086, lateral view, ×60, BOO72. K, O, Sb elements. K, NMV P143083, lateral view ×60, BOO18.6. O, NMV P143087, lateral view, ×60, TQ6. P, Sc element, NMV P143088, lateral view, ×45, BOO18.6.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to 12 feet thick, and thin beds of quartzite, chert and slate' on the southern margin of his map of the Aberfeldy district. The locality (Fig. 2, loc. 1), *c.* 105 m downstream from the crossing of 4-wheel drive road 'Deep Creek No. 2', has numerous cobbles of various lithologies including a fine sandstone with angular quartz clasts 2–3 mm across. We found dolomitic arenite megaclasts but not limestone blocks the size of those noted by Baragwanath in the section exposed in the bed of Deep Creek, obtaining only one prospective, highly crinoidal limestone clast (*c.* 20 cm across); this produced conodonts, but poorly.

2. Thinly bedded, rhythmically banded, calcareous argillites and argillaceous limestones, lacking macrofossils, outcropping on the right (east) bank of Deep Creek 50–55 m downstream from its junction with Scatabit Creek. This proved barren of conodonts. Several similar occurrences, lacking macrofossils, were noted in Deep Creek and in Scatabit Creek below the Gladstone Track crossing.

3. Immediately east and stratigraphically beneath the limestone body of loc. 4 are sandstones and polymict conglomerates, including limestone clasts up to 0.5 m across, outcropping in the bed of Deep Creek. Samples were taken from a tabular clast of crinoidal limestone *c.* 2 cm in thickness (loc. 3A), and from a rounded clast *c.* 30 cm in thickness (loc. 3C).

4. The 'Middle Crossing' Deep Creek limestone body interpreted by us as a megaclast. It is in fact the large body of limestone reported by Baragwanath (1925) as outcropping in Deep Creek '2 miles south' of the southern boundary of his Aberfeldy geological map. The distance given was a misprint; it should have read 5 miles. Samples were taken mid-way up the south flank of the outcrop (loc. 3S) and from the topographically highest point (loc. 3W).

5. Lower 'Toongabbie marble quarry', Marble Creek. Because of discordant relationships to adjacent strata (Kitson 1925), we consider this to be a megaclast.

6. Upper 'Toongabbie marble quarry', Marble Creek. Because of discordant relationships to adjacent strata (Murray 1887, p. 46, 1895, p. 38), we consider this to be a megaclast.

7–11. Spot localities in 'Murray's Gully', Tyers (see Fig. 1). We consider this body to be autochthonous, a repetition of the main Tyers–Boola development of Coopers Creek Limestone.

12. Limestone, including prominent stylobreccia, outcropping on the left bank of the Tyers River beneath the bridge about 750 m south-southwest of Tyers Quarry. The productive sample came from the left bank of the river a few metres downstream from the bridge abutment; samples from about the northern abutment of the bridge proved barren.

13. Oval nodules of mid-grey variably calcareous argillite mostly 6 cm or less but up to 20 cm in length, in rhythmically banded siltstones/argillites (?Wilson Creek Shale) outcropping in the bed of Scatabit Creek *c.* 15–20 m upstream from the crossing of the 'Gladstone Creek' 4-wheel drive road. Occasional fossils seen in cross-section are brachiopods, rugose corals and ?bactritids or *Coleolus*. No conodonts were found in the acid-insoluble residues.

14. A crinoidal limestone clast (not *in situ*) from Deep Creek *c.* 550 m upstream from its junction with Scatabit Creek, lithologically identical with the crinoidal limestone clast acid-leached from loc. 1.

15. White Rock (or Colonial Sugar Refineries) Quarry, Coopers Creek. Interpreted as allochthonous, emplaced within the Boola Formation. VandenBerg (1975) noted two megaclasts at this locality.

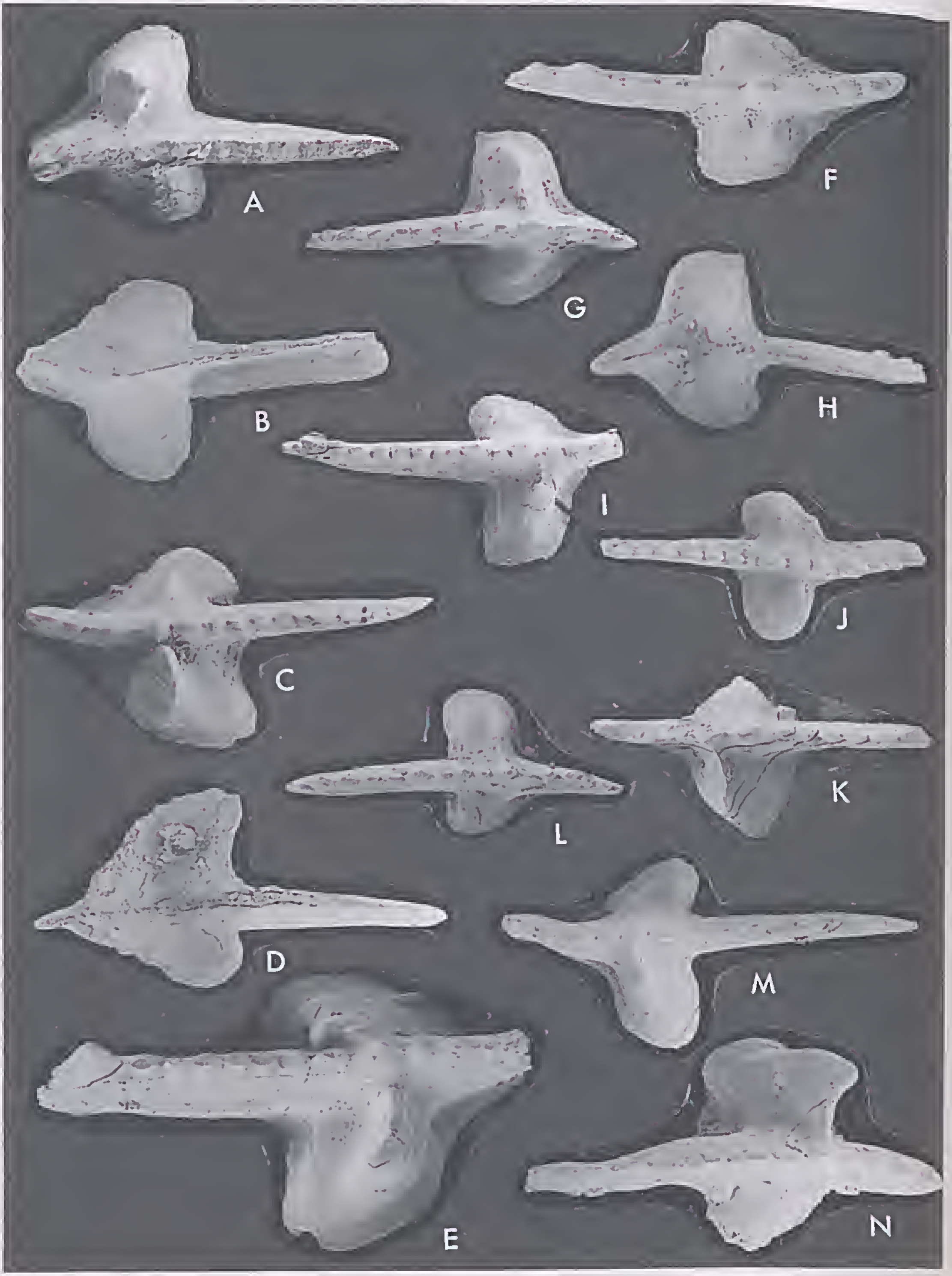
16. Evans Brothers Quarry, Coopers Creek. Cooper (1971) identified, *inter alia*, *Eognathodus sulcatus* from this locality. VandenBerg (1975) regards this megaclast as emplaced low within the Wilson Creek Shale.

17. Small outcrop of limestone on Platina–Coopers Creek road 460 m towards Coopers Creek from the bridge over the former Moe–Walhalla railway at Platina.

18. Megaclast of bioclastic limestone outcropping in a minuscule quarry on the Platina–Coopers Creek road 610 m towards Coopers Creek from the bridge over the former Moe–Walhalla railway at Platina.

19. Limestone spall, presumably from Evans

Fig 11. A–G, *Pandorinellina steinhornensis miae* (Bultynck 1971), all Pa elements. A, NMV P143089, lateral view, ×60, TQ/0-0.2. B, NMV P143090, lateral view, ×60, BOO16.5. C, NMV P143091, upper view, ×60, BOO16. D, NMV P143092, lower view, ×60, BOO13.8. E, NMV P143093, lateral view, ×60, BOO14.5. F, NMV P143094, lateral view, ×45, BOO43.8. G, NMV P143095, upper view, ×60, BOO20.1. H–L, *Ancyrodelloides omus* alpha morph Murphy & Matti 1983, all Pa elements. H, I, NMV P143096, upper and lower views respectively, ×60, BOO13.8. J, NMV P143097, upper view, ×45, BOO13.8. K, L, NMV P143098, upper and lower views respectively, ×45, BOO13.8.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Brothers' Quarry, on old road upslope from Platina–Coopers Creek road, *c.* 350 m towards Coopers Creek from the bridge over the former Moe–Walhalla railway at Platina.

20. Loose blocks of conglomerate and conglomeratic sandstone with carbonate matrix in a gutter on the west side of Telbit Road (Thomas 1942) at grid reference 421961 on Vicmap 1:25 000 topographic map 8122-2-3 Tyers Junction. Samples from this locality, regarded as Boola Formation by VandenBerg (1975), were processed by Cooper (1971) and by us but no conodonts were obtained.

Nine limestone occurrences were not sampled:

21. An outcrop in the left branch of White's Creek, Tyers (Rehfisch & Webb 1993), interpreted as a northward extension of the Murray's Gully tract (locs 7–11).

22. An outcrop shown by Thomas (1942) between the White Rock and Evans Brothers quarries at Coopers Creek.

23. Limestone within the Wilson Creek Shale outcropping in the Thomson River about 0.65 km south-east of White Rock Quarry, Coopers Creek (Thomas 1942; Carey & Bolger ms.).

24. An occurrence of autochthonous limestone within the Wilson Creek Shale in Jacobs Creek, Moondarra (Carey & Bolger ms.)

25. An occurrence, now submerged beneath Lake Thomson, of 'highly fossiliferous limestone and calcareous strata partly metamorphosed by granodiorite' 'with a maximum width of about 20 feet and a length of 60–70 feet' outcropping on the east flank of the Thomson River '¼ mile south of Cascade Creek' (Baragwanath 1925, pp. 22 and 39, note 24).

26. Limestone clasts in conglomerate 'near the steel bridge (Poverty Point Bridge) over the Thomson River, about two miles north of its junction with Stringer's Creek' (Junner 1914, p. 289). A small sample from this locality has already failed to yield conodonts (Cooper 1971).

27. A body of limestone, assumed to be a clast, 'a couple of feet long and one foot thick, thinning out to nothing upwards and downwards and entirely enclosed by slates' reported by Murray (1895) as outcropping in the bed of Marble Creek.

28. A small occurrence reported by Kitson (1925, fig. 131) along strike northwards from the lower quarry at Marble Creek.

29. An outcrop reported by Herman (1901, p. 13) from Ostler's Creek, south of the Marble Creek limestone megaclasts and seemingly approximately on strike with them.

ACKNOWLEDGEMENTS

We dedicate this report to William Baragwanath Jr and O. A. L. Whitelaw who, without the benefit of aerial photographs, 4-wheel drive transport, excavations for engineering projects, or a multiplicity of roads, jeep tracks, and consequent road cuttings, mapped much of the mountainous and heavily forested terrain of east-central Victoria in the late 1890s and the beginning of this century. With pack horse and dumpy level they investigated all mines and, as well, contoured and surveyed the drainage pattern for the entire region. Above all, they were responsible for working out its basic geological structure. One of us (JAT) has fond memories of long conversations with Mr Baragwanath on the geology of this and other regions of Victoria whose geology and mines he knew in astonishing detail.

The project received its basic support from the Australian Research Council. Stephen Carey and David Holloway provided much useful information on the Deep Creek localities; Stephen Carey and John Webb kindly made available unpublished manuscripts, respectively on the geology of Deep Creek, and on sedimentation in the Tyers–Boola area; Barry Cooper provided a copy of his unpublished report (Cooper 1971) on acid-leaching samples from 5 localities in the southern part of the Walhalla Synclinorium. Glenn Brock, Michael Engelbretsen, Steven Monk, Karen Novotny, Gray Slater, and Terry Sloan energetically assisted with sampling; Terry Furey-Grieg was enthusiastic tally clerk for the distribution charts; Michael Engelbretson did the acid-leaching and SEM photography; he and Carol-Ann Brock printed the photos; Margaret Anderson carried out the sodium polytungstate separations; Alison De Pomeroy expedited the plate making; Judy Davis drafted the

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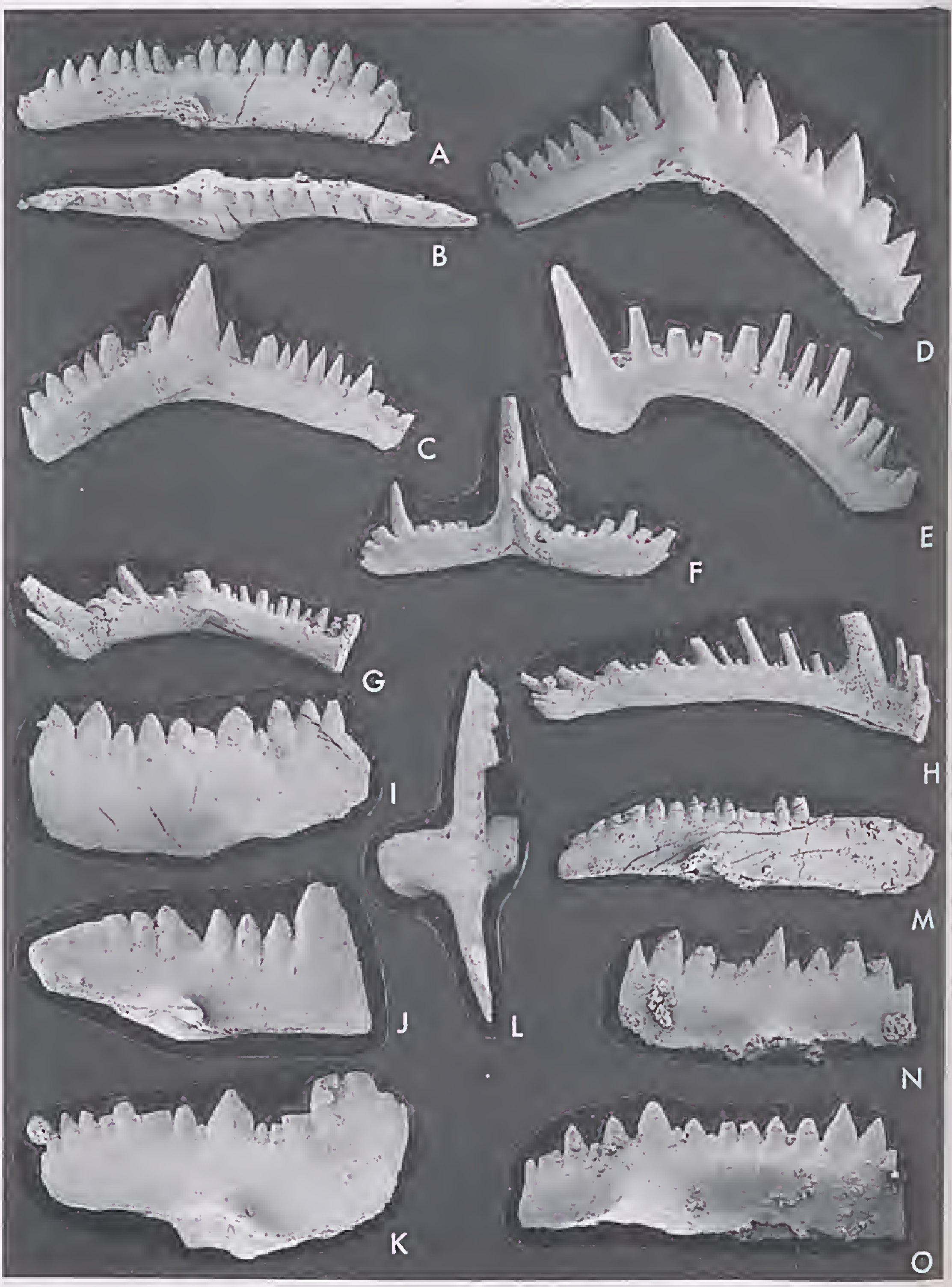
Fig. 12. A–N, *Ancyrodelloides omus* beta morph Murphy & Matti 1983, all Pa elements. A, B, NMV P143099, upper and lower views respectively, ×45, BOO7.8. C, D, NMV P143100, upper and lower views respectively, ×45, BOO6.2. E, NMV P143101, upper view, ×60, TQ loose. F, NMV P143102, upper view, ×60, TQ11.8–11.9. G, H, NMV P143103, upper and lower views respectively, ×45, BOO6.2. I, NMV P143104, upper view, ×60, BOO7.8. J, NMV P143105, upper view, ×45, BOO11.1. K, NMV P143106, upper view, ×45, TQ9.1. L, NMV P143107, upper view, ×45, TQ9.1. M, NMV P143108, upper view, ×45, TQ11.8–11.9. N, NMV P143109, upper view, ×60, TQ9.1.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figures and Glenn Brock drew up the charts. Stephen Carey, John Pickett and Fons VandenBerg read and commented helpfully on the manuscript. We are grateful to all the above for their expertise, interest and support.

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Fig. 13. A–H, *Ozarkodina excavata excavata* (Branson & Mehl 1933). A, Pa element, NMV P143110, lateral view, ×45, Loc. 4S. B, Pa element, NMV P143111, upper view, ×45, Loc. 4S. C, Pb element, NMV P143112, lateral view, ×45, Loc. 4S. D, Pb element, NMV P143113, lateral view, ×60, TQ6.6–6.7. E, M element, NMV P143114, lateral view, ×60, TQ6.6–6.7. F, Sa element, NMV P143115, lateral view, ×45, TQ7.3. G, Sb element, NMV P143116, lateral view, Loc. 4S. H. Sc element, NMV P143117, lateral view, ×45, Loc. 4S. I, *Ozarkodina remscheidensis repetitor* (Carls & Gandl 1969), Pa element, NMV P143118, lateral view, ×75, BOO6.2. J, *Ozarkodina ?confluens* (Branson & Mehl 1933), Pa element, NMV P143119, ×75, lateral view, Loc. 3A. K, L, *Pandorinellina optima* (Moskalenko 1966), Pa elements. K, NMV P143120, lateral view, ×90, BOO2.8. L, NMV P143121, upper view, ×45, Loc. 7. M, *Ozarkodina* sp., Pa element, NMV P, 143122, lateral view, ×30, TQ/0–0.2. N, O, *Ozarkodina remscheidensis remscheidensis* (Ziegler 1960), Pa elements, lateral views. N, NMV P143123, ×90, Loc. 3A. O, NMV P143124, ×60, Loc. 6.

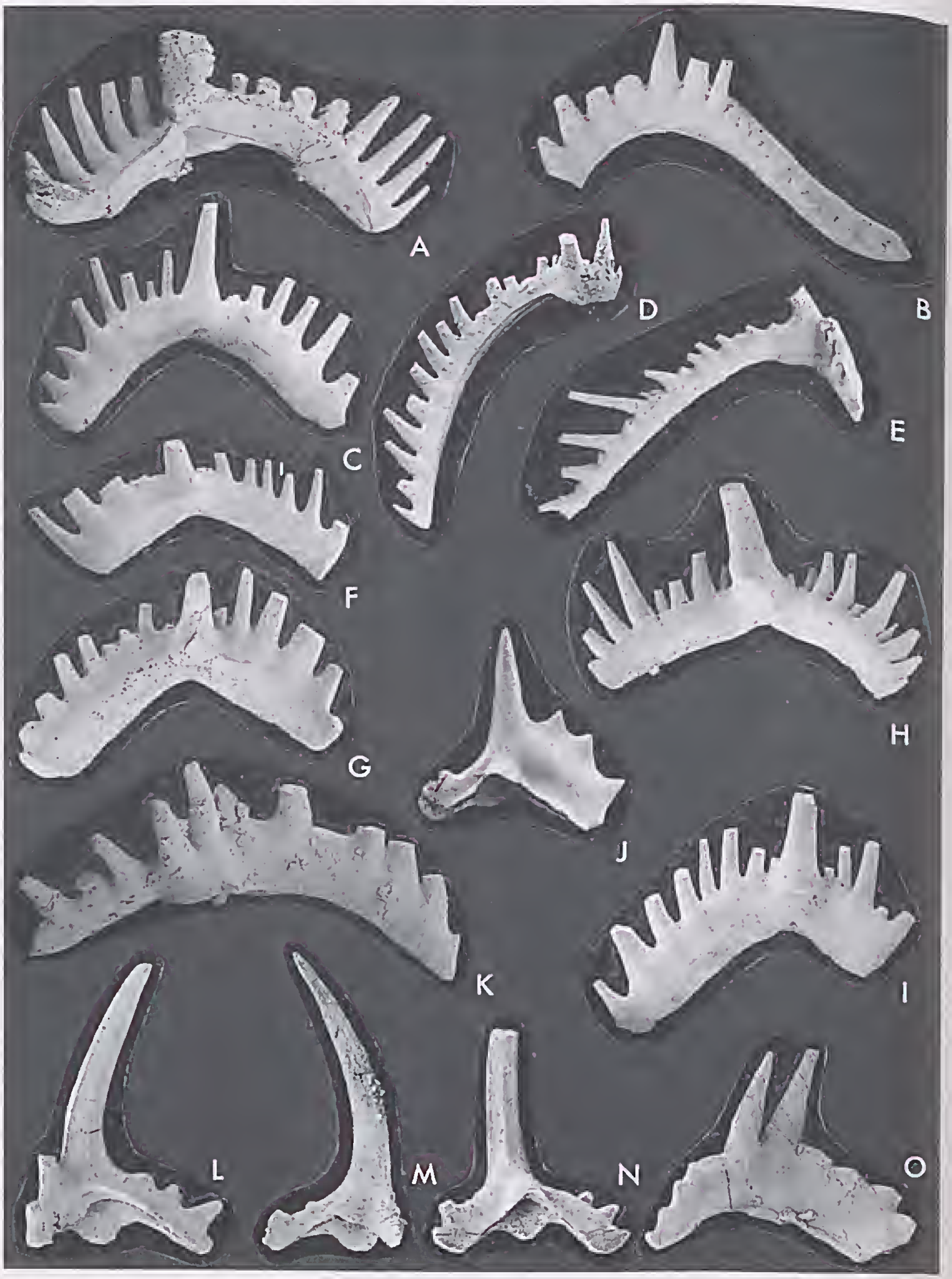
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Fig. 14. A–I, *Oulodus* cf. *walliseri* (Ziegler 1960), all lateral views. A, Pa element, NMV P143125, ×45, Loc. 3C. B, Pb element, NMV P143126, ×45, TQ11.8–11.9. C, G, I, Sa elements. C, NMV P143127, ×45, TQ11.8–11.9. G, NMV P143131, ×45, BOO11.1. I, NMV P143133, ×45, BOO1.8. D, M element, NMV P143128, ×45, Loc. 4W. E, Sc element, NMV P143129, ×45, Loc. 4W. F, H, Sb elements. F, NMV P143130, ×45, BOO1. H, NMV P143132, ×45, Loc. 9. J, *?Amydrotaxis* Pb element, NMV P143134, ×45, BOO72. K, *?Erika* sp. Pa element, NMV P143135, ×60, Loc. 4W. L–N, *Oulodus* sp. L, Sb element, NMV P143136, ×45, BOO43.7. M, Sc element, NMV P143137, ×45, BOO23. N, Sa element, NMV P143138, ×45, BOO45. O, Pathological form of *Oulodus* Pb element, NMV P143139, ×60, BOO70.

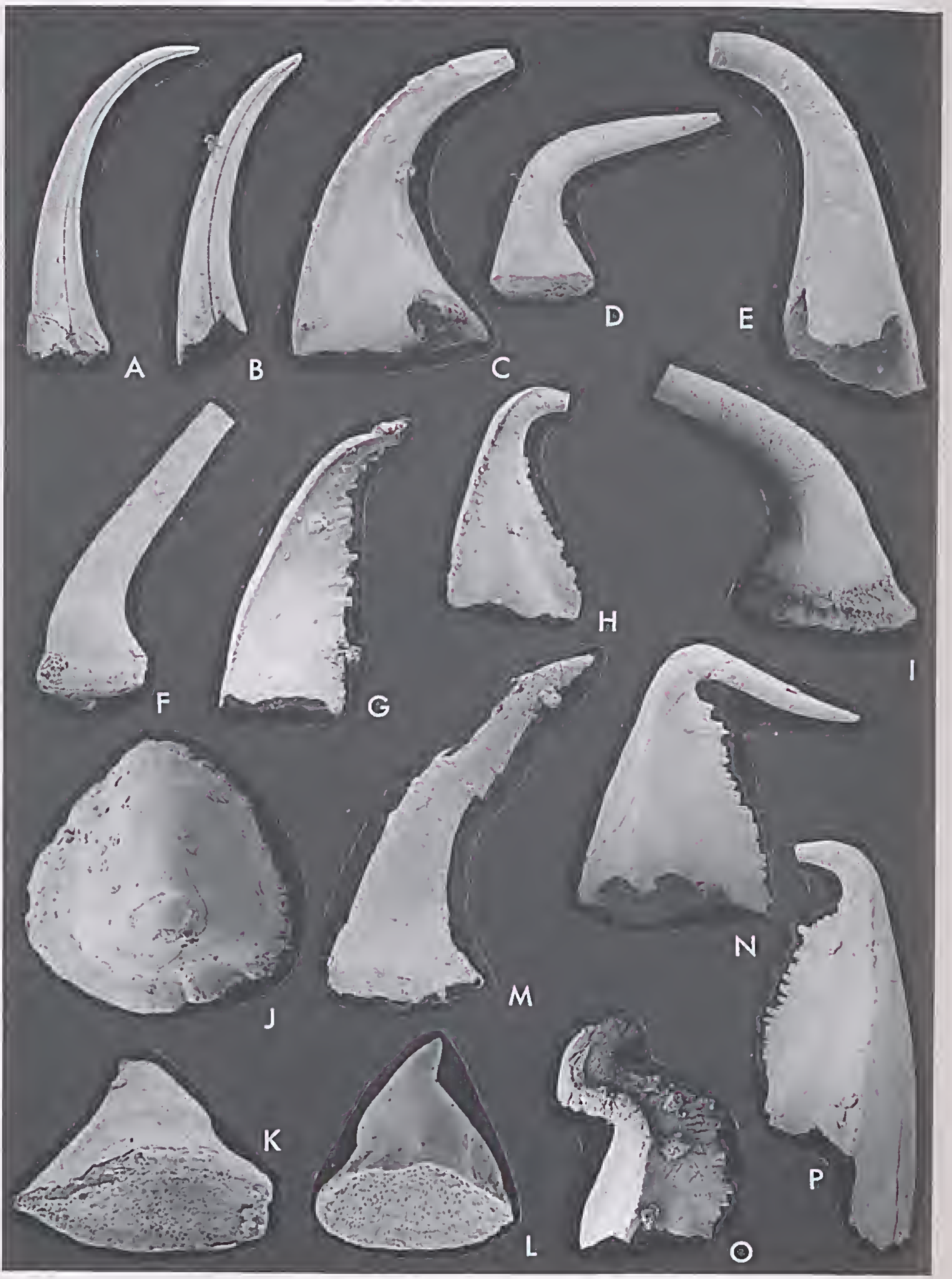
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Fig. 15. All except J are lateral views. A, *Neopanderodus aequabilis* Telford 1975, NMV P143140, ×45, BOO/0. B, *Panderodus unicostatus* (Branson & Mehl 1933), NMV P143141, ×45, BOO6.2. C, E, *Panderodus valgus* (Philip 1965). C, NMV P143142, ×90, TQ6.6–6.7. E, NMV P143144, ×90, TQ6. D, *Panderodus recurvatus* (Rhodes 1953), NMV P143143, ×75, BOO13.8. F, I, M, *Drepanodus* sp. F, NMV P143145, ×60, BOO13.8. I, NMV P143148, ×60, BOO23. M, specimen showing breakage, NMV P143152, ×75, Loc. 17. G, H, *Belodella resima* (Philip 1965). G, NMV P143146, ×75, BOO/0. H, NMV P143147, ×75, BOO/0. J–L, *Pseudooneotodus beckmanni* (Bischoff & Sannemann 1958). J, NMV P143149, upper view, ×90, TQ6.6–6.7. H, NMV P143150, ×90, TQ6.6–6.7. L, NMV P143151, ×90, TQ6.6–6.7. N–P, *Belodella triangularis* (Stauffer 1940). N, NMV P143153, ×90, BOO3.8. O, Pathological specimen, NMV P143154, ×60, BOO/0. P, NMV P143155, ×60, BOO49.

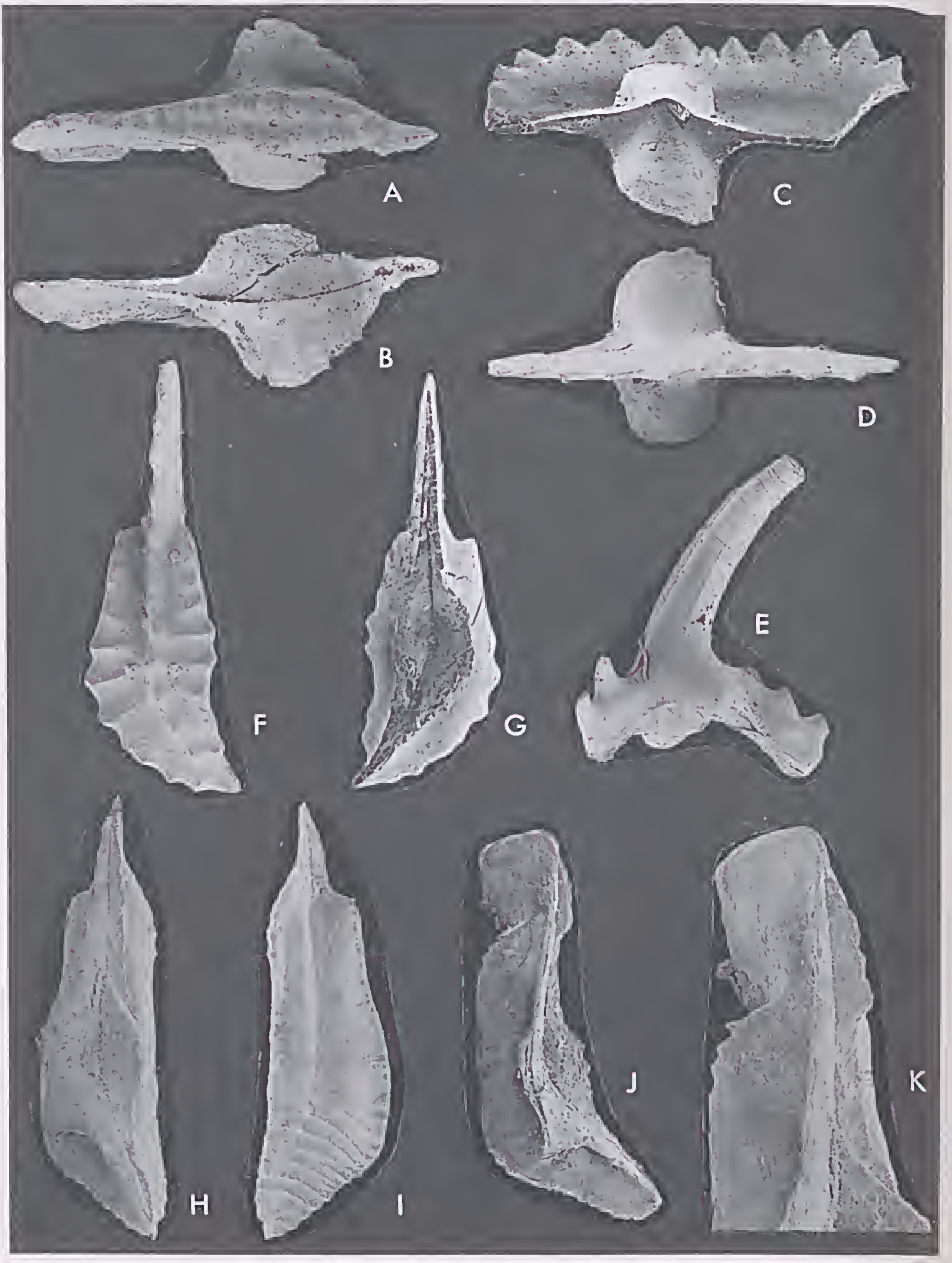
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Fig. 16. A, B, *Eognathodus sulcatus* Philip 1965, lambda morph. NMV P143156, upper and lower view respectively, ×60, Loc. 16. C, D, *Ozarkodina pseudomiae* Mawson 1992. NMV P143157, lateral and upper views respectively, ×90, Loc. 12. E, *Oulodus* sp. NMV P143158, ×45. F–K, *Polygnathus dehiscens* Philip & Jackson 1967. F, G, Juvenile specimen, NMV P143159, upper and lower views respectively, ×75, Loc. 12. H–K, New SEM photographs of holotype, University of New England F9173/1, lower, upper and two lateral views respectively. H–J, ×55. K, ×100, from the Cavan Formation 'in road cutting *c.* 350 yards W. of Taemas Bridge, Taemas, southern N.S.W.' (Philip & Jackson 1967). Note the damaged basal cavity in H, J and K.

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